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Relational Database for the Geology of the Northern Rocky Mountains–Idaho, Montana, and Washington

Prepared in cooperation with the Idaho Geological Survey and the Montana Bureau of Mines and Geology

Data Series 371

U.S. Department of the Interior
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Conventions

Names of databases, tables, forms and queries are shown in Times font, boldface type.

Field names (column headers) in tables are shown in italics.

To clarify which table is being discussed in relation to a particular field, the field name may be preceded by the table name and a period, and the whole term is shown only in italics (for example, *MUO.MU_id* for the *MU_id* field in the **MUO** table)

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Abstract

A relational database was created to prepare and organize geologic map-unit and lithologic descriptions for input into a spatial database for the geology of the northern Rocky Mountains, a compilation of forty-three geologic maps for parts of Idaho, Montana, and Washington in U.S. Geological Survey Open File Report 2005-1235. Not all of the information was transferred to and incorporated in the spatial database due to physical file limitations. This report releases that part of the relational database that was completed for that earlier product. In addition to descriptive geologic information for the northern Rocky Mountains region, the relational database contains a substantial bibliography of geologic literature for the area.

The relational database **nrgeo.mdb** is available in Microsoft Access version 2000, a proprietary database program. The relational database contains data tables and other tables used to define terms, relationships between the data tables, and hierarchical relationships in the data; forms used to enter data; and queries used to extract data.

Introduction

The process of compiling geologic maps is complex and time consuming and producing a geologic-map compilation in a digital format is even more complicated. Databases designed to hold and display spatial information in a geographic information system (GIS) often cannot store lengthy descriptive text. Complex relationships between data stored in various tables cannot easily be shown in map products. This report describes a relational database of geologic map-unit descriptions, lithologic descriptions, and a bibliography that was designed to capture geologic-map information and provide that data to the **nr_geo** spatial database published in Zientek and others (2005). This report is not a user manual.

The **nrgeo.mdb** relational database contains descriptions for 3,465 geologic-map units from both original geologic-map sources and the resultant geologic-map compilation by Zientek and others (2005). This database exemplifies how converting existing published geologic-map data into a compilation where all geologic information is stored in a single relational database can be accomplished. Both the original geologic-map data and the data generated from the compilation are stored and related so that the user can identify the source material for the compilation. It is also possible to use this data in conjunction with GIS products that contain a field having the same identifier.

Acknowledgments

We would like to thank Reed Lewis of the Idaho Geological Survey (IGS) for his assistance in interpreting some of the published maps. Louden Stanford (IGS) provided map descriptions in digital format. Karen Porter, Dick Berg, and Ken Sandau of the Montana Bureau of Mines and Geology, provided digital files of geologic-map descriptions for several of the Montana 1:100,000-scale geologic maps. Ellen Burch, contractor, scanned-map unit descriptions from paper maps and documents and converted them to text by using optical character recognition software. Karen Lund, Mike O'Neil, and Greg Green of the U.S. Geological Survey (USGS) provided digital pre-publication data for the database. Boyan Brodarick of the Canadian Geological Survey, and Bruce Johnson and Gary Raines (USGS) provided input to the database design. Bruce Johnson provided an Access database containing tables following the DGMDM 4.3 design (Johnson and others, 1999). Dave Bedford, Ryan Stevens, and Jordan Hastings (USGS) provided Visual Basic programming that was utilized in some of the database coding.

Pamela Dunlap and Matt Granitto reviewed the report.

Data Acquisition

The process of acquiring and incorporating existing data into the **nrgeo.mdb** relational database was a multistage process. Data in a text format that could not be obtained digitally were acquired by using optical character recognition (OCR)

software, which converts text from paper documents and maps to a digital format. The digital text data were then formatted for input into a spreadsheet program. The information for each map unit was parsed into various cells in a Microsoft Excel spreadsheet, and additional information was added to each record: a unique identification number for each record, an abbreviated source-map name, a source identification number, and the type of map object. These data were then imported from the spreadsheet into the **MUO** table of the **nrgeo.mdb** Access database. Map-unit descriptions acquired in Microsoft Access database format from the IGS were imported into the **nrgeo.mdb** database tables.

Database-Coding Procedure

After the raw data were incorporated into the database, Microsoft Access input forms were used to assist in standardizing terminology and to code additional fields with interpreted data. Where possible, the coder (evaluator) was a geologist who had been involved in creating the source map, or who had first-hand knowledge of the geology of the area.

Because the coders were not co-located, the database was replicated, and a copy was given each evaluator. Specific map units were assigned to each coder to prevent more than one person from working on the same records. Look-up tables were created and used as standards against which the data were checked for quality assurance. The database replicas were synchronized periodically with the master database. After the coding was completed, the data were reviewed for consistency and obvious errors were corrected.

Database Description

The **nrgeo.mdb** relational database contains data tables, as well as other components used to relate the data tables, to provide hierarchical structure, and to provide mechanisms for data entry and data query (table 1).

Database Tables

There are 19 tables in the **nrgeo.mdb** database (table 1; note that all tables are at the back of this report): 7 data tables, 7 look-up tables, 2 join tables, and 2 tree tables. Each individual table and its purpose is described in the following paragraphs. Relationships between the tables are shown in figure 1. Several look-up tables were designed to standardize input; they are used to produce outputs and serve as lists of valid values for some fields in the data tables. The join tables allow connections to be made between the data tables by defining relationships between particular fields. The tree tables are used to produce hierarchical simplifications of rock-type and stratigraphic-age terms.

Brief descriptions of the tables and definitions of the fields in the tables are also included in the digital files. (Tables and their descriptions are listed in the Database window; to view a list of fields and their definitions, highlight the table name and either click on the Design icon in the menu bar, or right-click on the table name and select Design View in the pop-up menu.)

Data Tables

MUO Table

The main data table, **MUO** (table 2), stores basic information about geologic-map units with records for both the regional-map units (*MU_id* greater than or equal to 10,000) compiled by Zientek and others (2005) and the original map units (*MU_id* between 1 and 4,977), as described on the forty-three source maps and databases. Map-unit descriptions (*MU_desc* field) for the regional-map units often are long and complex, because they were generated by concatenating descriptions from the source materials.

Two of the map-unit label fields, *MU_lab_gaf* and *MU_lab_gaf_or*, contain keyboard characters designated for use by the GeoAgeFullAlpha font set, a font set created by the U.S. Geological Survey to display special characters commonly used on geologic maps to indicate ages of rock units. (For example, *_ will display as PC when using the GeoAgeFullAlpha font set.) These special characters display as standard geologic-age symbols only in forms (for example, **MUO_frm**, **NR_pdf_qry_frm**) that are opened by using computers on which the font set is installed.

NR_Bib Table

A bibliography of the geology of the northern Rocky Mountain region is stored in the **NR_Bib** table (table 3). All references cited on the original source maps and related documents used to generate the regional compilation (Zientek and others, 2005) are included in the **NR_Bib** table. The table design allows for queries and sorts by author, date, title, name of publication, and map scales.

The database contains many references that were acquired by scanning the reference lists from the source-map publications and from other sources related to the geology of the northern Rocky Mountain region. While not an exhaustive listing, the bibliography contains more references than those cited in Zientek and others (2005).

NR_Lith Table

The **NR_Lith** table (table 4) contains lithologic (rock composition) information about each geologic-map unit. The table mainly contains interpretations of lithology based on the map-unit descriptions from the source maps. Three fields (*primary_lith*, *subordinate_lith*, and *incidental_lith)* contain lithologic terms extracted from the original map-unit descriptions and differentiated based on linguistic interpretations. That is, a set of rules was developed to attempt to capture the mapper's intent.

In order to populate the *dom_lith* field , the terms in the *primary_lith* field were used to select a representative dominant lithology term from the look-up table **NR_Lith_LU**, a master list of lithologic terminology.

Additional information in the **NR_Lith** table includes the geologic or morphologic form of the unit (*unit_form*), if known; yes/no entries to identify unit descriptions that contain economic information (*econ_geol*); evaluators (*lith_eval*) and their comments (*lith_comment*); and the rule used to parse the lithology terms into the various fields (*lith_process*).

Information in the *dom_lith* field was exported to the *lname_dom* and *uname_dom* fields in the **NR_GEO.LITH** and **NR_GEO.UN** tables of the **NR_GEO** spatial database (Zientek and others, 2005), respectively. Data in the *primary_lith* field were exported to the *name_majr1* and *name_majr2* fields in the **NR_GEO.LITH** table and the *name_major* field in the **NR_GEO.UN** table. Attributes in the *subordinate_lith* field were exported to the *name_minor* field in the **NR_GEO.LITH** and **NR_GEO.UN** tables, and information in the *incidental_lith* field was exported to the *name_other* field in the **NR_GEO.LITH** and **NR_GEO.UN** tables.

NR_Map_Title Table

The **NR_Map_Title** table (table 5) contains the map titles for maps that were used in the regional compilation by Zientek and others (2005) and is related to table **MUO** by the *map_tile* field. This table provides the source-map title and spatial database map-tile information on the form **NR_pdf_qry_frm**.

NR_Rock_Comp Table

Data from the **NR_Rock_Comp** table (table 6) was not included in the regional compilation by Zientek and others (2005). **NR_Rock_Comp** was populated by separating all the terms in the *primary_lith*, *secondary_lith*, and *incidental_lith* fields of the **NR_Lith** table into individual records and importing them to the *rock_name* field. Due to a lack of volume percentages of the various lithologies within each map-unit description in the source literature, a lithology rank

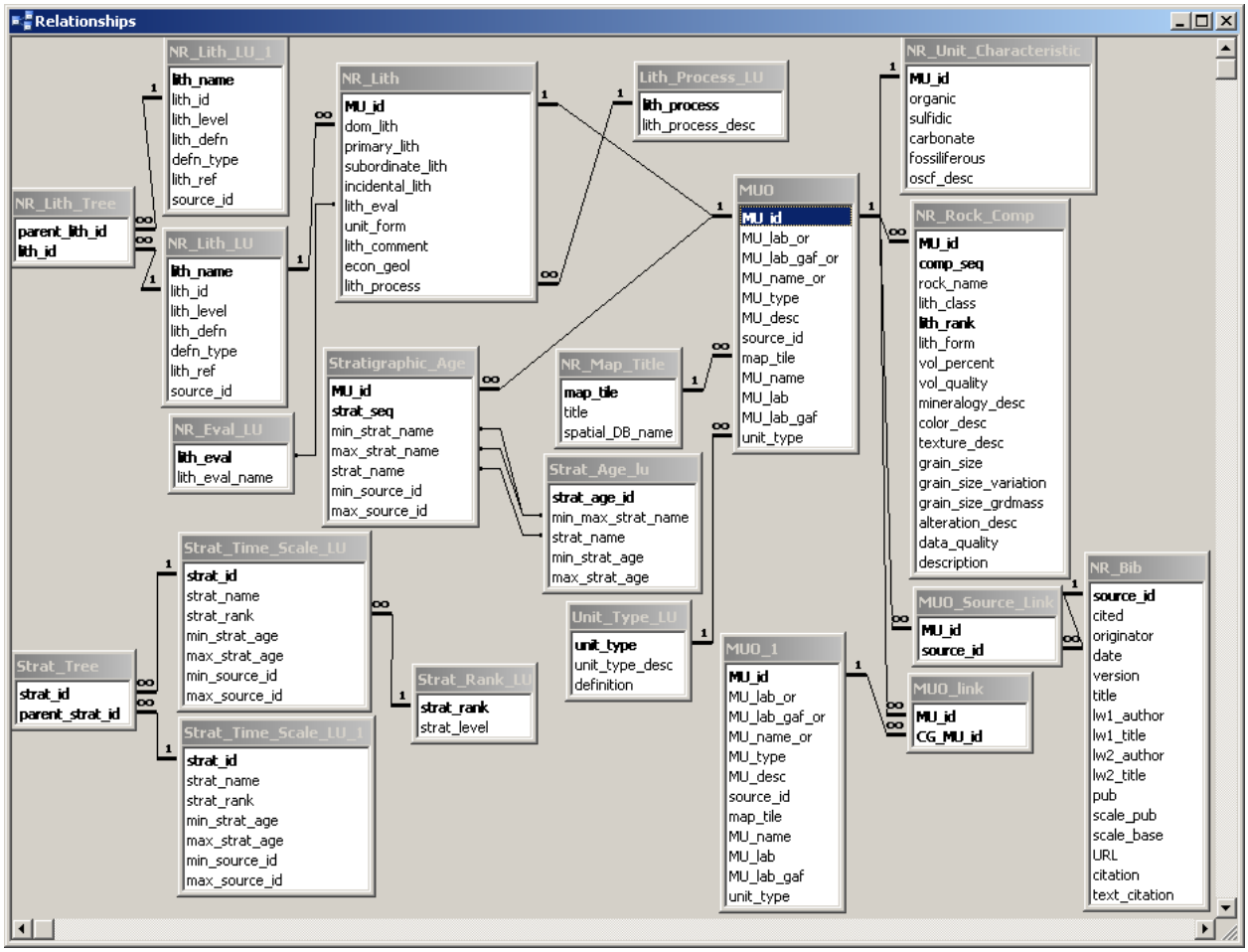

Figure 1. Relationships between tables in the **nrgeo.mdb** database. (Bold-faced text designates primary key fields. Infinity symbol indicates the "many" table in a many-to-one join.)

(*lith_rank*) of 1, 2, or 3 was assigned depending on whether the data was derived from the *primary_lith*, *secondary_lith*, or *incidental_lith* field, respectively. In cases where the same rock type was listed in two or more of these fields, the rank was assigned according to the most important field (where *primary_lith* > *secondary_lith* > *incidental_lith*). For example, if both *primary_lith* = sandstone and *secondary_lith* = sandstone for the same map unit, then *lith_rank* = 1.

Other than parsing rock terms into individual records, assigning a rank, and removing duplicates, no coding of other fields in this table was done. The other fields (table 6) are available for future attribution.

NR_Unit_Characteristic Table

The **NR_Unit_Characteristic** table (table 7) contains interpreted data. The table identifies rock units containing certain physio-chemical properties. Most of the field attributes are Boolean (yes/no) and indicate whether or not a particular property is present within the unit. A "yes" does not mean that that property is present throughout the unit, but that it is present in at least some of the rocks.

The binary fields provide a means to categorize map units based on factors such as: contains organic material, contains sulfides, contains carbonates, or contains macrofossils. These determinations are based almost entirely on the written descriptions provided by the map-unit sources. Some data were improved by examining secondary sources, but most of the determinations relied on primary-source map descriptions.

Stratigraphic_Age Table

The **Stratigraphic_Age** table (table 8) contains the stratigraphic ages of the rocks in the map units in the northern Rocky Mountains compilation (Zientek and others, 2005). The table contains both a minimum and a maximum age for each map unit, as well as a term that combines the minimum- and maximum-age terms and generalizes that term to a geologic-period term. A higher-level term is used in the *strat_name* field if the period-age level is not possible. There are a few map units of unknown age.

Look-Up Tables

NR_Eval_LU Table

The look-up table **NR_Eval_LU** (table 9) contains a list of the names and initials of the people who evaluated and entered map-unit data into the database. This table was used to determine which initials to use for the people who coded the lithologic data (in attributing the *lith_eval* field of the **NR_Lith** table). It should be noted that the look-up table **NR_Eval_LU** was not used as a digital drop-down or pick list for automated data entry.

NR_Lith_LU Table

The look-up table **NR_Lith_LU** (table 10) is a list of lithology terms for use in populating the *dom_lith* field of the **NR_Lith** table. It also provides definitions and references for the lithologic terminology, as well as a value to indicate hierarchical level within this classification system.

Geologic terminology provides several ways to describe rocks. This descriptive terminology ranges from general field terms based on megascopic characteristics to terms based on microscopic, geochemical, genetic, physical, or some combination of these properties. Because the source material for the map compilation used rock terms generated and defined by several different classification schemes, the authors did their best to convert the terms to a single scheme that is composition-based. This was not always possible; the list of terms in the **NR_Lith_LU** table also contains terms that describe rock genesis (in addition to rock composition).

Strat_Age_LU Table

The look-up table **Strat_Age_LU** (table 11) contains geologic age terms used in the *Strat_name* field in the **Stratigraphic_Age** table. In order to provide a single age term for a map unit, terms were hyphenated for map units that spanned two or more age ranges. Hyphenated terms begin with the youngest term and end with the oldest (for example, Eocene-Late Cretaceous). The table also provides terms that are generalized to the geologic period or higher-level term (for example, Tertiary-Cretaceous). The table is not comprehensive of all possible terms; it only includes ages that were used on the maps compiled in Zientek and others (2005). The table does not contain undefined terms used by authors, such as late Paleozoic or middle Tertiary. Where used, these terms were recoded as 'Paleozoic' or 'Tertiary' when more detailed information did not exist.

This table can be used to create a list of map units in chronologic order by using the numerical fields *min_strat_age* and *max_strat_age*. A query ordered by "Sort ascending" on either of these fields will produce a list with the youngest unit at the top and ascending in age to the oldest unit at the bottom.

Strat_Rank_LU Table

The look-up table **Strat_Rank_LU** (table 12) is based on the North American Digital Geologic Data Model v. 4.3 (Johnson and others, 1999). The *strat_level* field is used to assign a hierarchical level to the stratigraphic-rank attributes (for example, eon, epoch, era, period) listed in the *strat_rank* field in the look-up table **Strat_Time_Scale_LU**.

Strat_Time_Scale_LU Table

The look-up table **Strat_Time_Scale_LU** (table 13) contains the geologic-age terms used in this database. Several published geologic time scales were examined for use of terminology and age ranges in this database: Haq and Van

Eysinga (1998), Hansen (1991), Palmer (1998), Palmer and Geissman (1999), Remane (2003), and Wilson (2001). No one source contained all the names used in the source maps. Haq and Van Eysinga (1998) and Hansen (1991) presented the best combination of names and dates for stratigraphic ages, and these two sources were chosen to use for the time-scale.

The *strat_rank* field for the Precambrian age was coded as "eon" rather than the correct term "informal" to enable the user to create a hierarchical list of stratigraphic ages if relatively equivalent terms existed in one column (field).

The **Strat_Time_Scale_LU** table is used to code the *min_strat_age* and *max_strat_age* fields in the **Stratigraphic_Age** table.

Lith_Process_LU Table

The look-up table **Lith_Process_LU** (table 14) provides descriptions of the parsing rules listed in the *Lith_process* field in the **NR_Lith** table. The assumptions and philosophy used to convert linguistics (inconsistently formatted text strings) to a categorical system (standardized) are described in Zientek and others (2005, appendix E).

Unit_Type_LU Table

The look-up table **Unit_Type_LU** (table 15) defines the codes used in the *unit_type* field of the **MUO** data table. The look-up table provides terms to classify the map units, based on their geologic unit name, into one of five categories: formal name, informal name, informal part of formal unit, not a geologic unit, unconsolidated unit.

Join Tables

MUO_link Table

The **MUO_link** table (table 16) is a special type of join table that provides a connection (defines a relationship) between the source-map units and the compiled regional-map units in the **MUO** data table. This self-joining or reflexive relationship makes it possible to generate and store records for the output units in the same table that contains records for the input units. The **MUO_link** table was used to ensure that unique *MU_id* values were created for all of the output units and that all output units matched an existing set of input values.

MUO_Source_Link Table

The **MUO_Source_Link** table (table 17) is an intermediate table needed to provide one-to-many joins between the **MUO** and the **NR_Bib** tables. Without the **MUO_Source_Link** table, the relationship between the two data tables would be many-to-many, and it would be impossible for the software to link records. This intermediary table sets up a one-to-many-to-one relationship: one *MUO_id* in the **MUO** table can be connected or joined to many *MUO_id* values in the **MUO_Source_Link** table which in turn can be joined by using the *source_id* to one value in the **NR_Bib** table (as shown in figure 1).

Tree Tables

NR_Lith_Tree Table

Because most lithologic terms are based on a hierarchical classification system, it is possible to generalize terms. The **NR_Lith_Tree** table (table 18) is a special table that was constructed to enable users of the database to generalize lithologic descriptions of map units. The table can be used to generalize lithology terms listed in the **NR_Lith** table to any of five levels. By using the crosstab query Lith_hierachy_source_crosstab_qry, a full hierarchical list of terms can be generated for most of the map units (exceptions include some units that are represented as linear features by Zientek and others, 2005).

Strat_Tree Table

Stratigraphic ages are based on a hierarchical classification system that makes it possible to generalize or group ages. The **Strat_Tree** table was constructed to enable users of the database to group the ages for individual map units. The **Strat_Tree** table (table 19) can be used to group ages of map units to any of three levels. By using a crosstab query in the database, the ages can be grouped to eon, era, or period. An example query (**Strat_age_min_hierarchy_crosstab_qry**) is included in the database to group the map units by youngest (minimum) age.

Database Queries

There are six query routines in the database (table 1): two crosstab queries convert hierarchical data to a simple, tabular flat-file output format of rows and columns; two select queries provide the data to the crosstab queries; one select query supplies data for export to Adobe PDF; and one parameter query produces a generalized age list based on user input. Three of the queries can be invoked by the user in the initial start-up form. Two of the queries are called by the other queries.

NR_desc_pdf_qry Query

The **NR_desc_pdf_qry** query (fig. 2) provides descriptive map-unit data (from *the* **MUO** table) to the **NR_pdf_qry_frm** form. The query provides a mechanism to display the name of each original map unit with the name and other descriptive information for the corresponding compiled unit in a simple tabular format and as a form. The query uses the one-to-many relationship of the **MUO** table with the **MUO_link** table to show the stratigraphic ages assigned to the Northern Rocky Mountain map units of Zientek and others (2005) with the *MU_id* values in that report. The description field (*MU_desc*) is a memo field and was not included in the published ESRI Arc coverage format because that format does not allow inclusion of memo-type data fields (long text strings). Thus,

this query provides a mechanism to show lengthy descriptive data in a form that can be exported to PDF format.

Age_hierarchy_parameter_qry Select Query

The **Age_hierarchy_parameter_qry** query (fig. 3) is a parameter query. It allows the user to generalize units to a particular stratigraphic-age rank: eon, era, period, subperiod, or epoch. When this query is invoked, the user is asked to specify an age rank. The output lists (in the two far-right columns) the specific stratigraphic age (*strat_name*) and corresponding age rank (*Strat_Time_Scale_LU_1.strat_rank)*. Records for rock units that have only been assigned a higher-level age will not appear in the output for generalization requests for lower-level age ranks (for example, generalizing to period when the rock unit's age is not attributed any finer than era will not return records for those units).

Users need to be careful when interpreting the results of this query because rock units are assigned both a minimum and a maximum age in the database. The query is designed to return the youngest (minimum) age of each map unit. For about 80 percent of the units, it does not matter which age field is used since most units have the same minimum and maximum age; however, it does make a difference for the other 20 percent. The query can be modified to output the maximum age by removing the join between *Stratigraphic_Age.min_strat_name* and *Strat_Time_Scale_LU.strat_name* and invoking a new join between *Stratigraphic_Age.max_strat_name* and *Strat_Time_Scale_LU.strat_name*.

Lith_hierarchy_source_qry Query

The **Lith_hierarchy_source_qry** query (fig. 4) is an intermediate query used to create necessary relationships so that a hierarchical tree of rock types can be constructed. This query provides data to the crosstab query **Lith_hierarchy_source_crosstab_qry**.

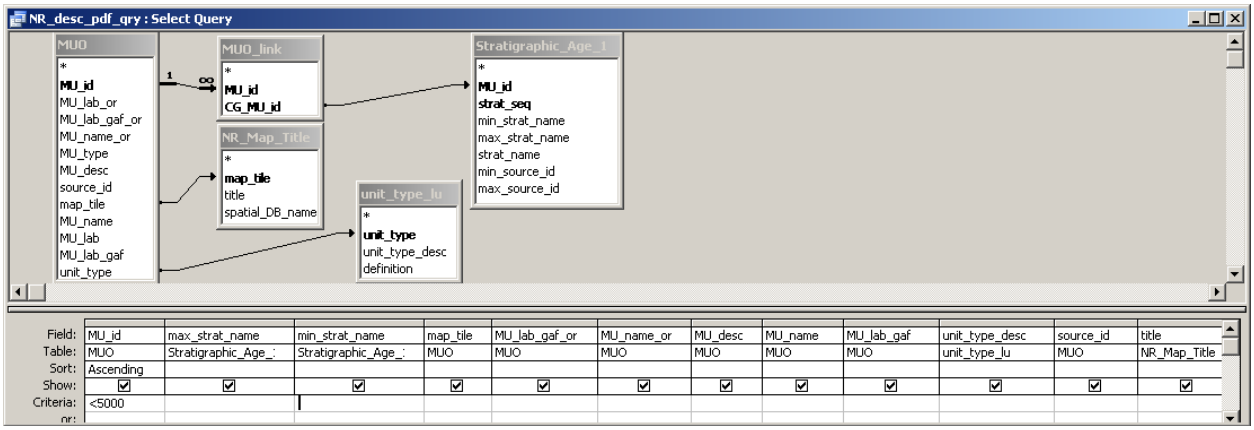

Figure 2. Design view of **NR_desc_pdf_qry** query.

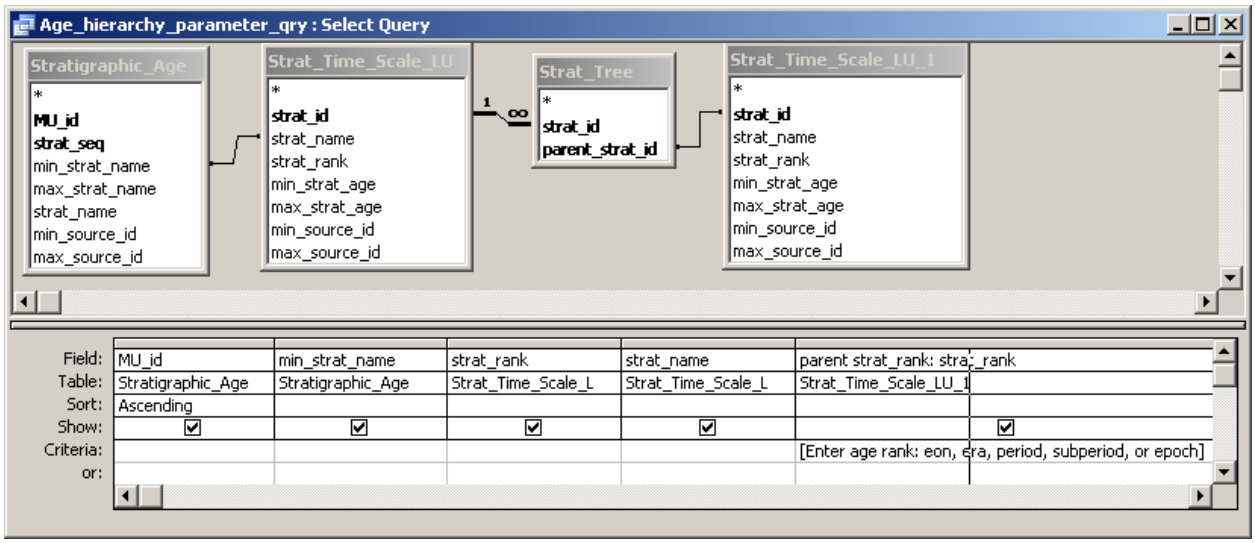

Figure 3. Design view of the **Age_hierarchy_parameter_qry** query.

Lith_hierarchy_source_crosstab_qry Query

The **Lith_hierarchy_source_crosstab_qry** query (fig. 5) provides a tabular output listing generalized rock terms at each of five hierarchical levels (see columns labeled *1* through *5* in fig. 6) for the dominant lithology (dom_lith) attribute for each map unit. Rock terms listed in the *1* column (most general lithologic name; corresponds to *lith_level* = 1 in the **NR__Lith_LU** table) were used to populate the *lname_1* field in the **nr_geo.lith** table and *uname_1* in the **nr_geo.un** table in the **nr_geo** spatial database of Zientek and others (2005), and so on for columns *2* through *5*. Any changes in the rock type assigned to a map unit (*dom_lith* in the **NR_Lith** table) will be reflected immediately in the output from this query.

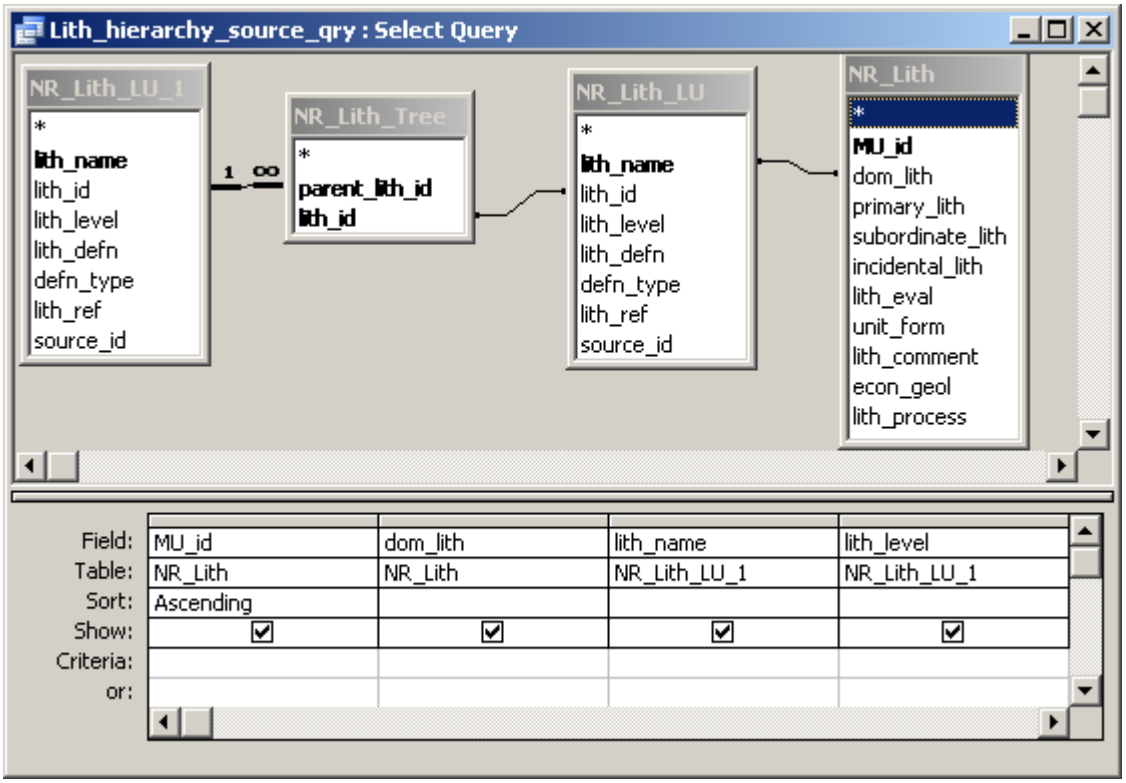

Figure 4. Design view of **Lith_hierarchy_source_qry** query.

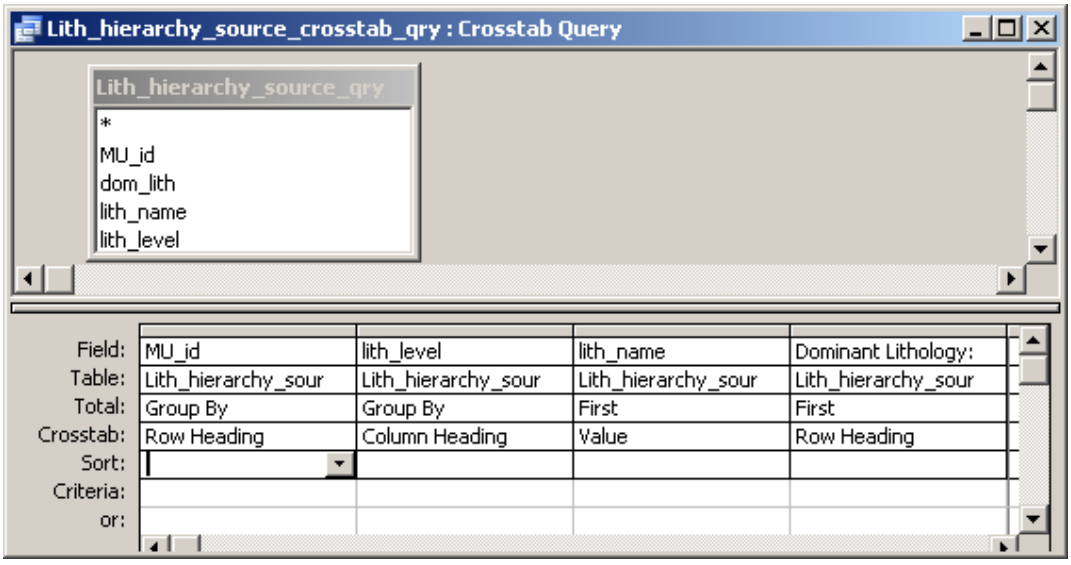

Figure 5. Design view of **Lith_hierarchy_source_crosstab_qry** query.

Strat_age_min_hierarchy_qry Query

The **Strat_age_min_hierarchy_qry** query (fig. 7) is an intermediate query used to create necessary relationships so that a hierarchical tree of map-unit ages can be constructed. This query provides data to the crosstab query **Strat_age_min_hierarchy_crosstab_qry**.

Strat_age_min_hierarchy_crosstab_qry Query

The **Strat_age_min_hierarchy_crosstab_qry** query (fig. 8) provides a tabular output showing the generalized age terms at each hierarchical level of age rankings (eon, era, period, subperiod, and epoch). [Labels for the column headings were modified in the Query Properties window for

Lith_hierachy_source_crosstab_qry : Crosstab Query

MU_id	Dominent Lithology	1	2	3	4	5
151	volcanic QAPF rocks	igneous-volcanic	volcanic QAPF rocks			
152	andesitoid-rhyolitoid (calc-alkalic) volcanic suite	igneous-volcanic	volcanic QAPF rocks	andesitoid-rhyolitoid (calc-alkalic)		
153	granitoid	igneous-plutonic	plutonic QAPF rocks	granitoid		
154	granodiorite	igneous-plutonic	plutonic QAPF rocks	granitoid	granodiorite	
155	granodiorite	igneous-plutonic	plutonic QAPF rocks	granitoid	granodiorite	
156	mixed siliciclastic/carbonate sedimentary rocks	sedimentary rock	mixed siliciclastic/carbonate sed			
157	mixed siliciclastic/carbonate sedimentary rocks	sedimentary rock	mixed siliciclastic/carbonate sed			
158	mixed siliciclastic/carbonate sedimentary rocks	sedimentary rock	mixed siliciclastic/carbonate sed			
160	siliciclastic and carbonate sedimentary rocks	sedimentary rock	siliciclastic and carbonate sedim			
161	mixed siliciclastic/carbonate sedimentary rocks	sedimentary rock	mixed siliciclastic/carbonate sed			
162	mixed carbonate/siliciclastic sedimentary rocks	sedimentary rock	mixed carbonate/siliciclastic sed			
163	mixed siliciclastic/carbonate sedimentary rocks	sedimentary rock	mixed siliciclastic/carbonate sed			
164	mixed siliciclastic/carbonate sedimentary rocks	sedimentary rock	mixed siliciclastic/carbonate sed			
165	conglomerate	sedimentary rock	siliciclastic sedimentary rocks	siliciclastic rocks with gravel-size	conglomerate	
166	siliciclastic sedimentary rocks	sedimentary rock	siliciclastic sedimentary rocks			
167	conglomerate	sedimentary rock	siliciclastic sedimentary rocks	siliciclastic rocks with gravel-size	conglomerate	
168	conglomerate	sedimentary rock	siliciclastic sedimentary rocks	siliciclastic rocks with gravel-size	conglomerate	

Record: 1 of 3451

Figure 6. Example of output from the **Lith_hierarchy_source_crosstab_qry** query.

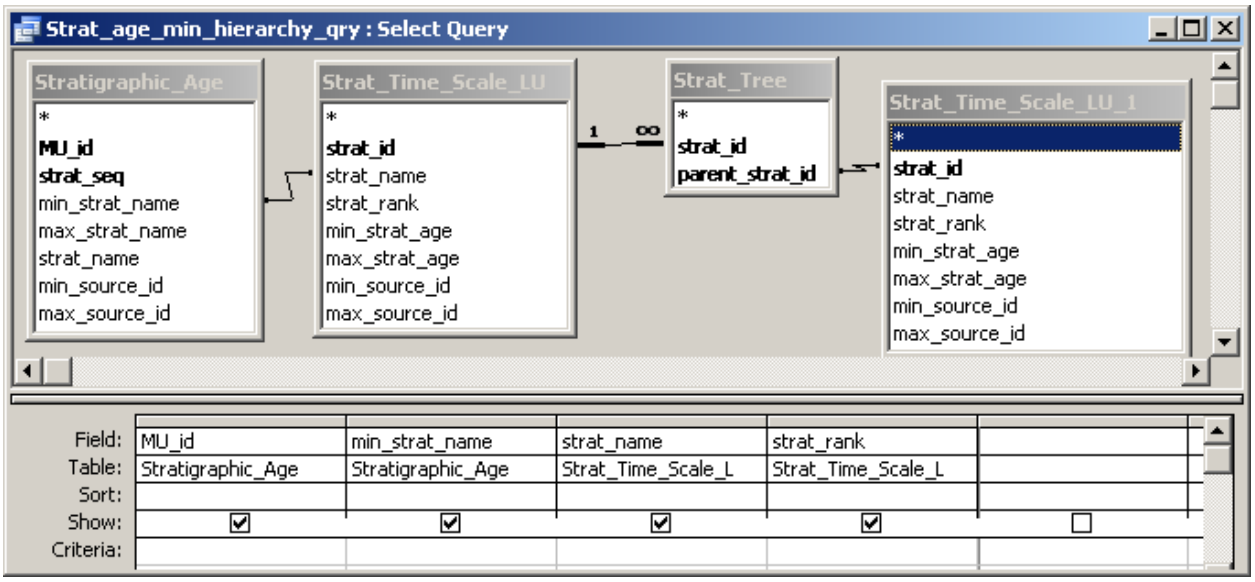

Figure 7. Design view of the **Strat_age_min_hierarchy_qry** query.

the "Column Heading" entry in the "Crosstab:" row of the design view of the **Strat_age_min_hierarchy_crosstab_qry** query to produce a view showing the columns in a sequence of most general to most specific (from left to right) (fig. 9).]

The output will not display hierarchical-name attributes for all map units because not all age ranks have age names, and finer (more specific) age rankings may not have been designated in the source map-unit descriptions (fig. 10).

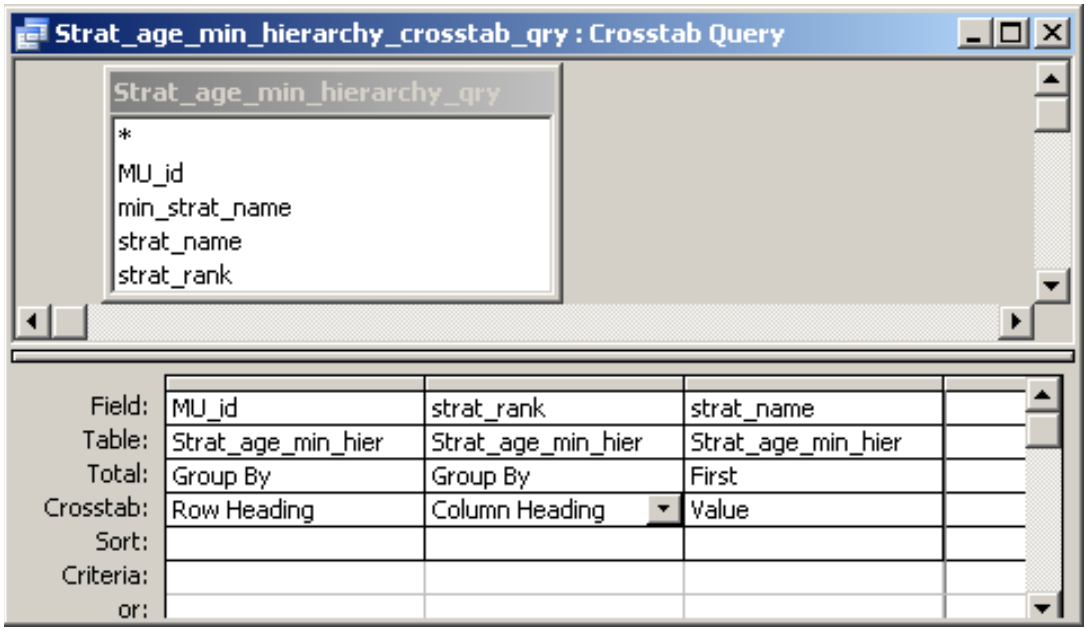

Figure 8. Design of the **Strat_age_min_hierarchy_crosstab_qry** query.

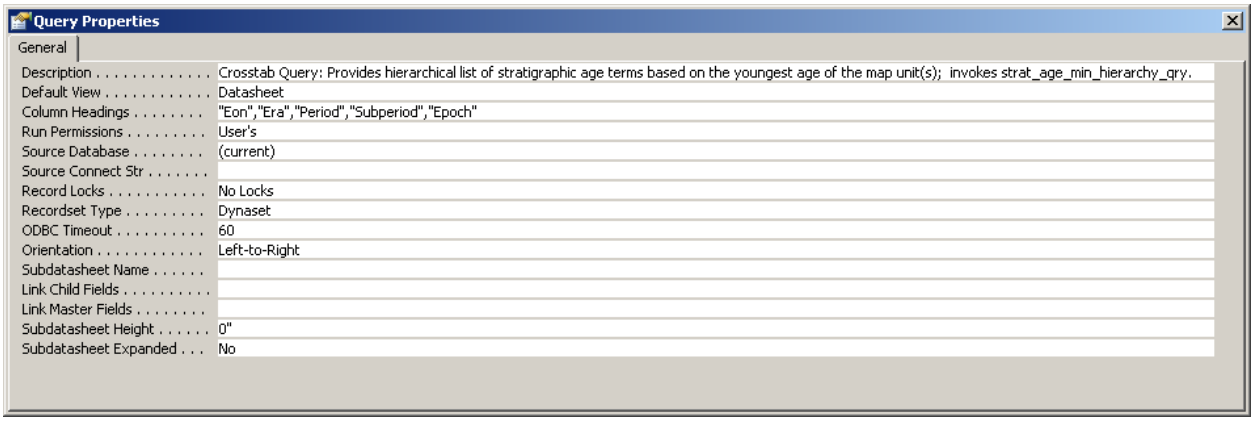

Figure 9. Query Properties window for the "Column Heading" entry in the "Crosstab:" row of the design view of the **Strat_age_min_hierarchy_crosstab_qry** query. (Shows entries used to designate columns headings in the output file.)

Database Forms

There are 11 forms in the database: 2 main forms, 7 subforms, 1 startup form, and 1 splash screen form (fig. 11). One main form, **NR_pdf_qry_frm**, is used to create portable document format (PDF) files [1]. The other main form, **MUO_frm**, is for data input. One subform, **NR_Bib_subfrm**, is embedded in the **NR_pdf_qry_frm** form. The other subforms are embedded in the **MUO_frm** form.

SplashScreen Form

The **SplashScreen** form (fig. 12) displays when the nrgeo.mdb database is opened, and it lists product information (report title, authorship, date of publication, publisher, and publication series information). It appears for 5 seconds and then closes.

1-Startup_frm Form

The **1-Startup_frm** form is a user-interface window (fig. 13) that automatically pops open after the introductory **SplashScreen** window closes. The buttons on this second window provide the user with an easy means of interacting with the database.

The button "Open Data Entry/View Form" opens the **MUO**_frm form, the button "Open Form to Print PDF" opens the **NR_pdf_qry_frm** form, the button "Run Age Parameter

Strat_age_min_hierarchy_crosstab_qry : Crosstab Query

MU_id	Eon	Era	Period	Subperiod	Epoch
150	Phanerozoic	Cenozoic	Quaternary		
151	Phanerozoic	Cenozoic	Tertiary	Neogene	Miocene
152	Phanerozoic	Cenozoic	Tertiary	Paleogene	Eocene
153	Phanerozoic	Cenozoic	Tertiary	Paleogene	Eocene
154	Phanerozoic	Mesozoic	Cretaceous		
155	Phanerozoic	Mesozoic	Cretaceous		
156	Phanerozoic	Paleozoic	Permian		Early Permian
157	Phanerozoic	Paleozoic	Permian		Early Permian
158	Phanerozoic	Paleozoic	Permian		Early Permian
160	Phanerozoic	Paleozoic	Permian		Early Permian
161	Phanerozoic	Paleozoic	Permian		Early Permian
162	Phanerozoic	Paleozoic	Permian		Early Permian
163	Phanerozoic	Paleozoic	Permian		Early Permian
164	Phanerozoic	Paleozoic	Permian		Early Permian
165	Phanerozoic	Paleozoic	Pennsylvanian		Middle Pennsylvanian
166	Phanerozoic	Paleozoic	Mississippian		Early Mississippian
167	Phanerozoic	Paleozoic	Mississippian		Early Mississippian
168	Phanerozoic	Paleozoic	Mississippian		Early Mississippian
169	Phanerozoic	Paleozoic	Devonian		Late Devonian
170	Phanerozoic	Paleozoic	Devonian		
171	Phanerozoic	Paleozoic	Devonian		
173	Phanerozoic	Paleozoic	Ordovician		
174	Proterozoic	Middle Proterozoic			
175	Proterozoic	Early Proterozoic			
300	Phanerozoic	Cenozoic	Quaternary		
301	Phanerozoic	Cenozoic	Tertiary	Neogene	Miocene
302	Phanerozoic	Cenozoic	Tertiary	Paleogene	Eocene
303	Phanerozoic	Cenozoic	Tertiary	Paleogene	Paleocene
304	Phanerozoic	Mesozoic	Cretaceous		Late Cretaceous

Record: 1 of 3463

Figure 10. Example of output from the **Strat_age_min_hierarchy_crosstab_qry** query.

[1]Both commercial and open-source software that will creat PDF files are available on the Internet.

Query" runs the **Age_hierarchy_parameter_qry** query, the button "Run Lithology Hierarchy Query" runs the **Lith_hierachy_source_crosstab_qry** query, the button "Run Strat Age Hierarchy Query" runs the **Strat_age_min_hierarchy_crosstab_qry** query, the button "Close This Form" closes the user-interface window, and the button "Close Database" closes the database and exits out of Access. The name (and a brief description) of the query or form that each button invokes is given in table 1 and fig. 11.

NR_pdf_qry_frm Form

The **NR_pdf_qry_frm** form uses data from the **NR_pdf_qry** query and the **NR_pdf_Bib_subfrm** form to provide the user with a view of descriptive information for each map-unit record in the database (fig. 14). Note that the entry in the text box for Description of Map Unit is truncated; only two lines of text are visible in the form as viewed onscreen. The data generated by using this form will, if printed to a PDF file, exceed

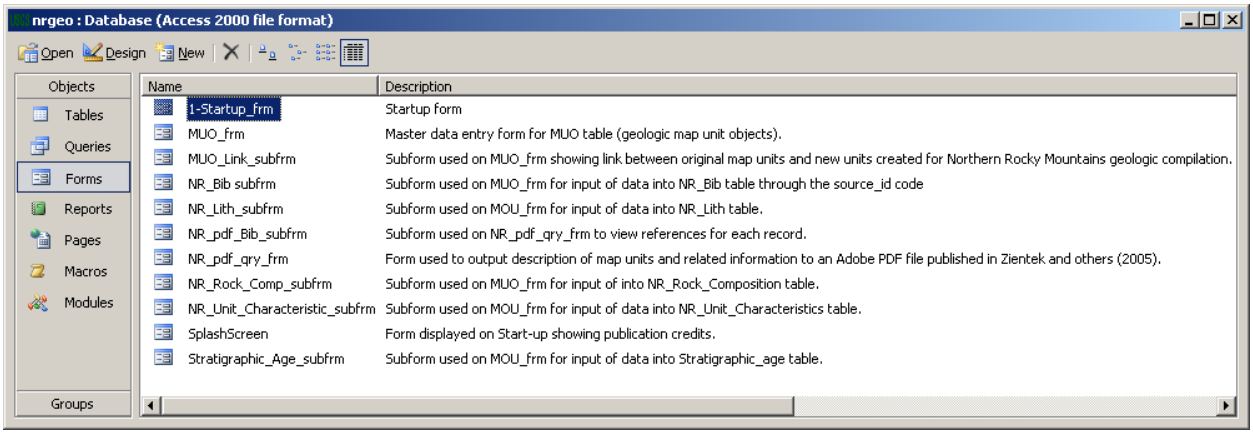

Figure 11. Forms and their description in **nrgeo.mdb** database.

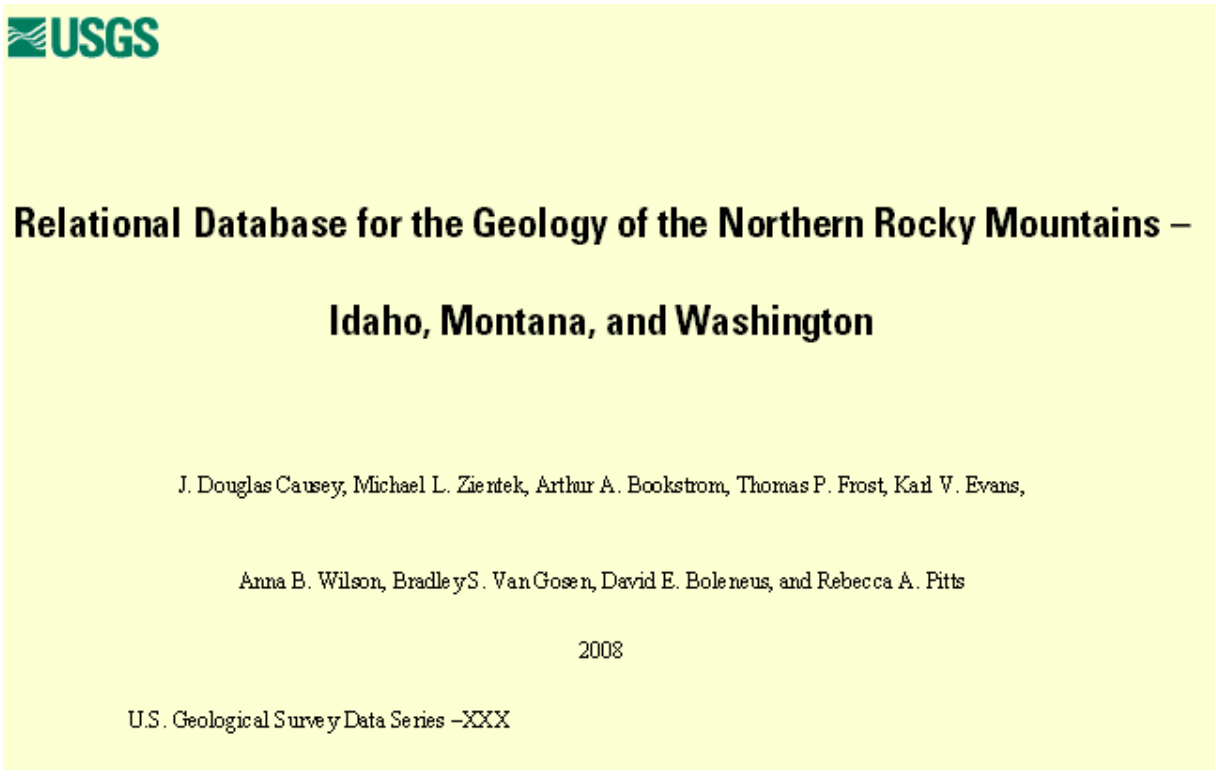

Figure 12. Window generated by the **SplashScreen** form.

2,000 pages. The resultant PDF can be searched or printed out on paper. [The user must have the appropriate software to generate the PDF file for which this form was designed.]

To generate an easy-to-read print version of the descriptive information, the Detail properties (in the Format tab and the All tab of the form) for the line "Force New Page" are set to "After Section" so that no more than one record is printed per page (fig. 15). In addition, the properties for several of the text boxes on the form are set to "Yes" for the property "Can Grow" in order to print out the entire entry, and others are set to "Yes" for the "Can Shrink" property so as to not print out blank lines and waste paper. The "grow" or "shrink" proper-

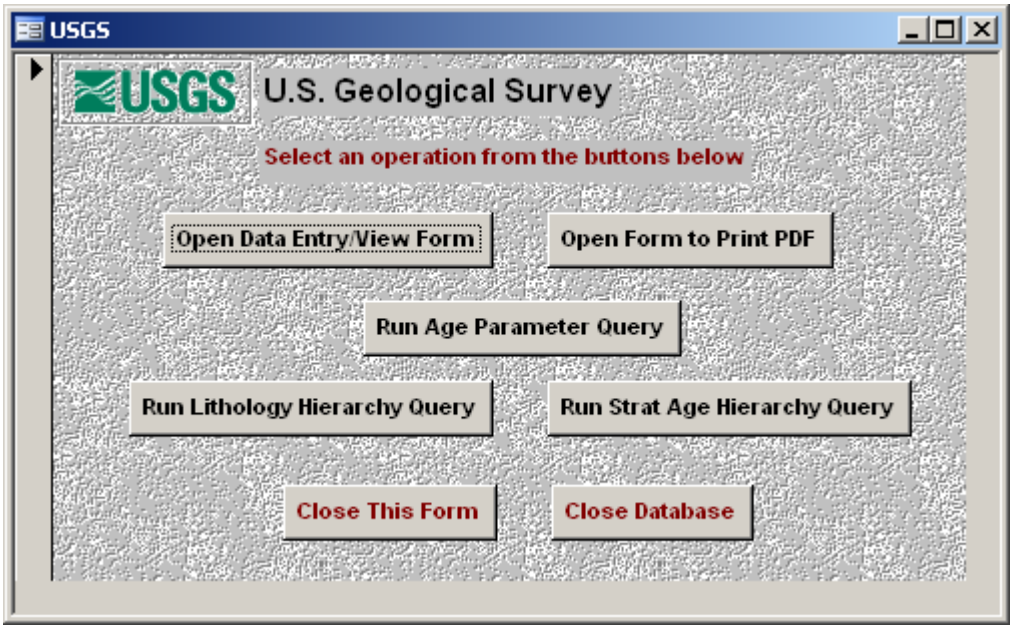

Figure 13. Window generated by the **1-Startup_frm** form.

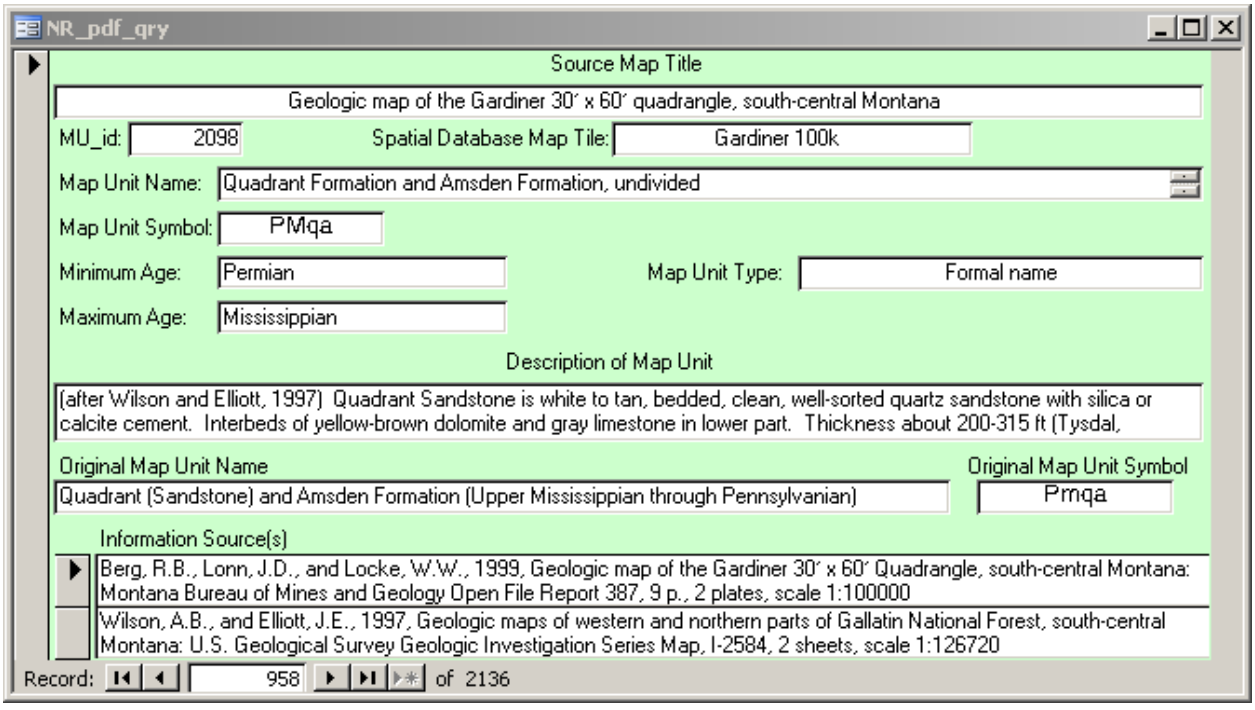

Figure 14. Example of the **NR_pdf_qry_frm** form. (Shows record for MU_id = 2098 in the nrgeo database.)

ties are only activated when the form is printed (as opposed to displaying onscreen; compare figs. 14 and 16). For text boxes that have been set to expand on printing, vertical scroll bars will appear in the form when the user left-clicks in the box; the user can then scroll through the lines to view the entire entry onscreen (see text box for Map Unit Name in fig. 14).

NR_pdf_Bib_Subfrm Form

The **NR_pdf_Bib_subfrm** form (fig. 17) provides the mechanism to display multiple information sources for a single geologic-unit (*MU_id*) record on the NR_pdf_qry_frm form (see fig. 14) by linking the *source_id* field in

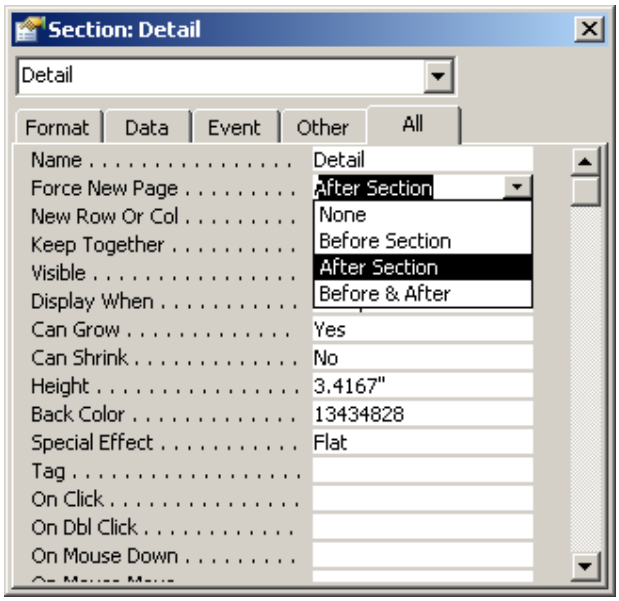

Figure 15. Properties for Detail section of Design view of the **NR_pdf_qry_frm** form.

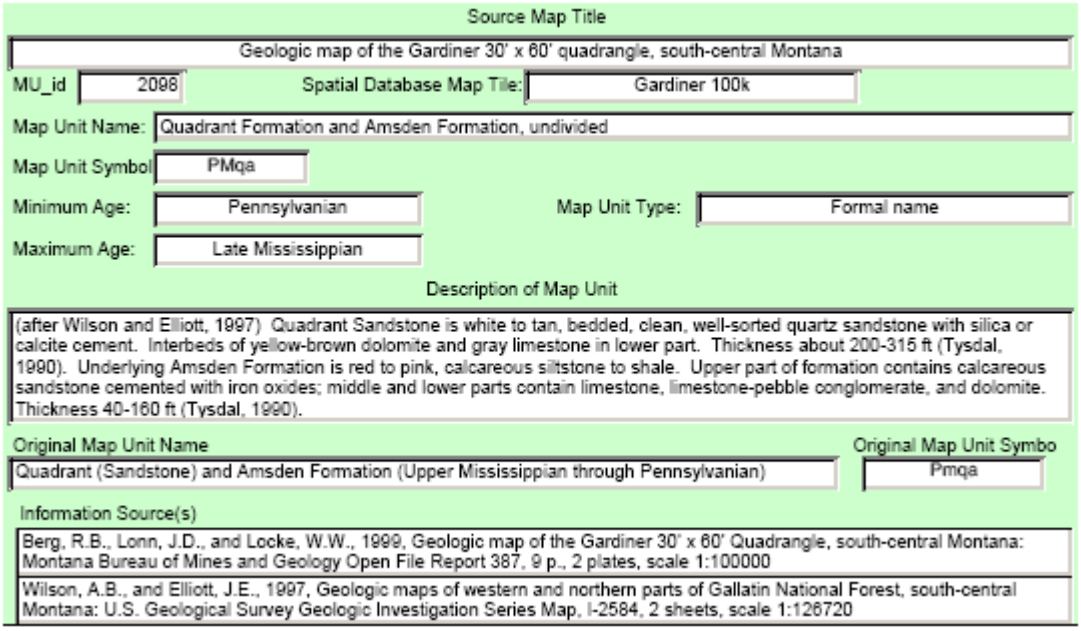

Figure 16. Example of printed output for *MU_id* = 2098 demonstrating how the "Can Grow" property, when set to "Yes" for the "Description of Map Unit" text box, permits the entire description to be printed.

the **NR_Bib** table to the *source_id* field in the **NR_pdf_qry** query. Once the link is made, the subform is inserted into the **NR_pdf_qry_frm** form. The Detail properties for the Information Source(s) text box in the Design view of the subform is set to "Yes" for both of the lines "Can Grow" and "Can Shrink".

MUO_frm Form

The **MUO_frm** form (figs. 18*A*-*E*) is both a data entry form (for use only after a new map-unit record has been entered into the database by using the **MUO** table) and a data-viewing form. Descriptive information entered into this form is automatically distributed into the various other data tables by means of connections provided by embedded subforms and tabbed pages.

The shaded text boxes in the form (for example, MU_id, Source_id, and Original unit name) serve as visual clues that the data in them should not be revised or altered. Information in the various original unit boxes represents primary-source language and symbology. The data property for these boxes is set to prevent editing: "Locked" is set to "Yes" in the Data tab listings (fig. 19).

A description of the contents of each field in the form is displayed in the bottom of the Access database window frame (see fig. 18*A*). Clicking in any data window will show the associated text for that field.

Each of the five tabbed pages (occupying the lower half of the form) displays fields from a single related table, thus allowing the user to grasp a whole view of the data for a map unit while working on any one of the five related tables: the

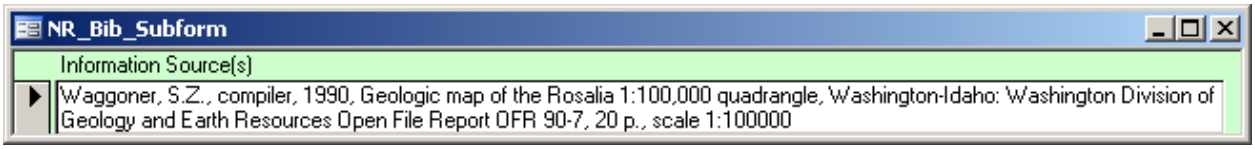

Figure 17. View of the **NR_pdf_Bib_Subfrm** form.

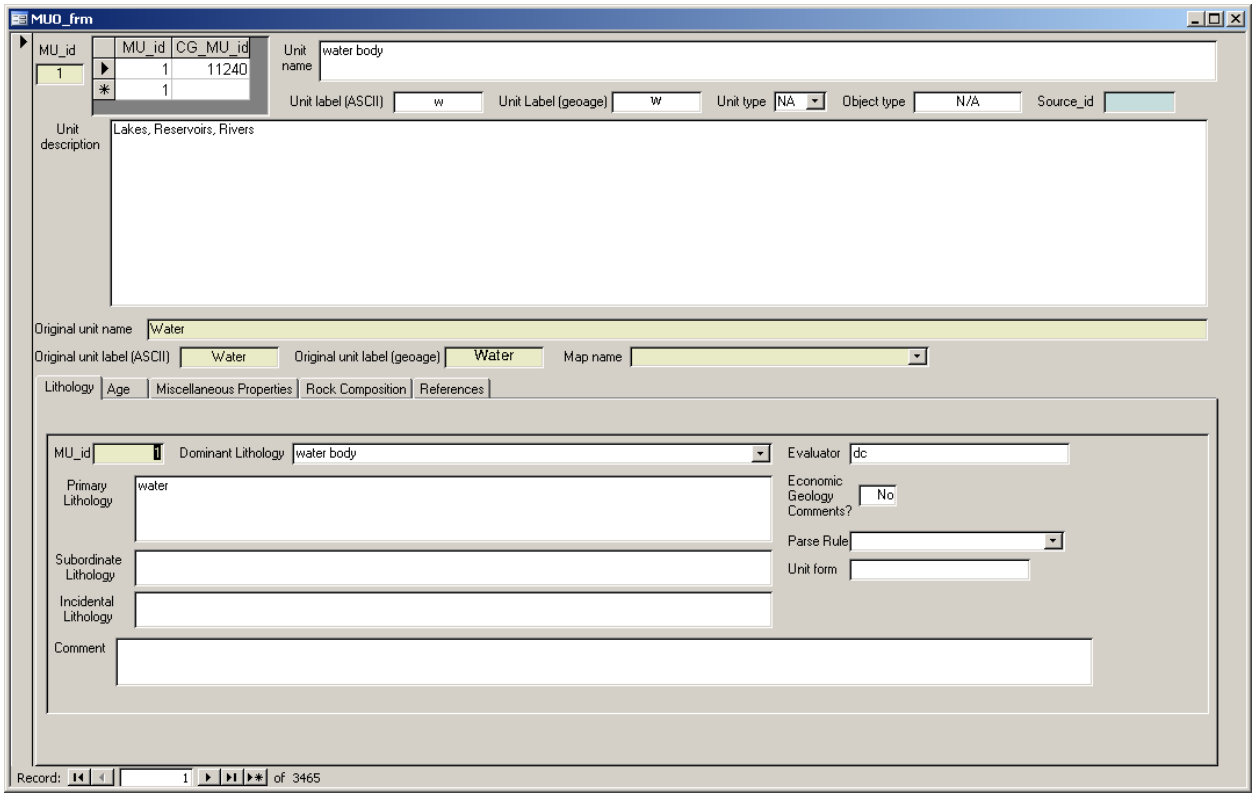

Figure 18*A*. View of the **MUO_frm** form. (The embedded **MUO_Link_subfrm** form displays as a correlation table in the upper left (between boxes for **MU_id** and Unit name); five page tabs positioned along a central horizontal represent five more embedded forms; the Lithology-tabbed page is open.)

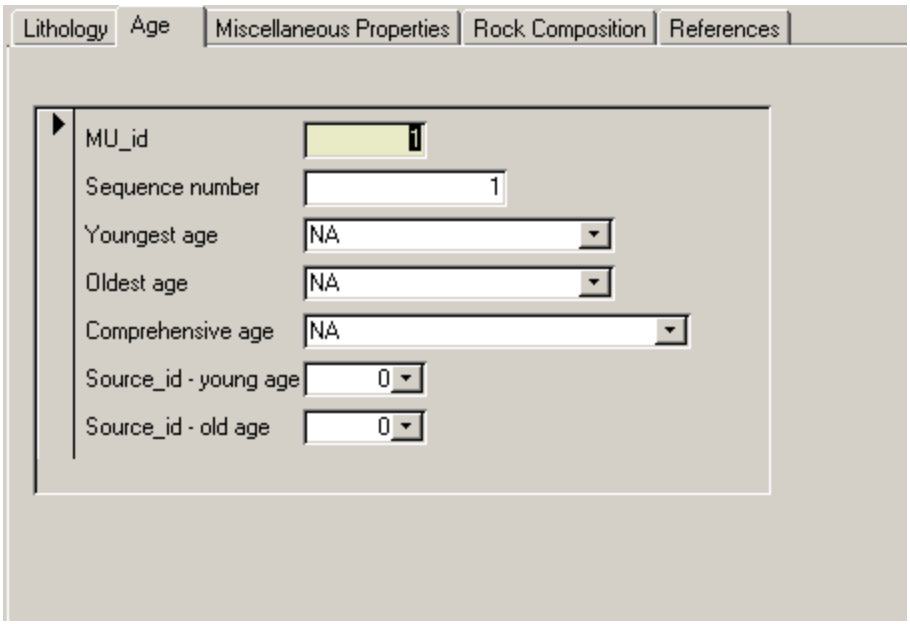

Figure 18*B*. View of layout for the Age-tabbed page in **MUO_frm** form.

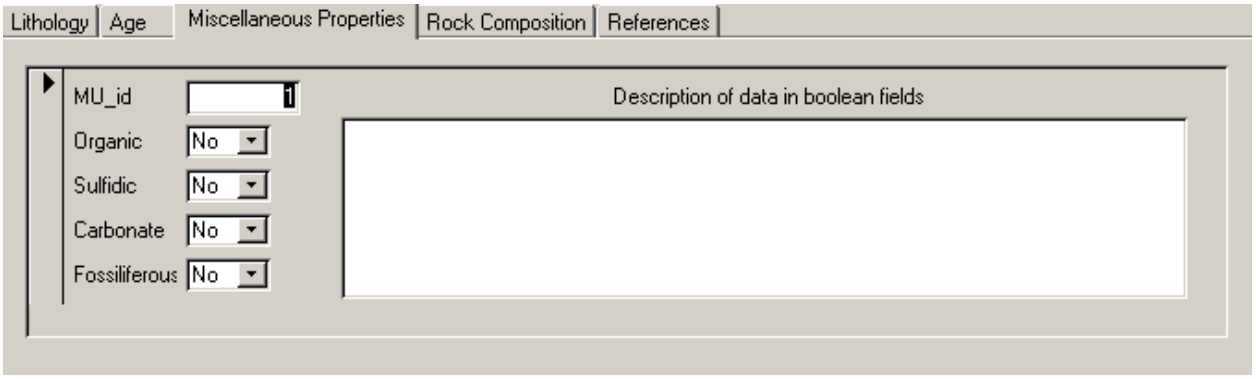

Figure 18*C*. View of layout for the Miscellaneous Properties-tabbed page in the **MUO_frm** form.

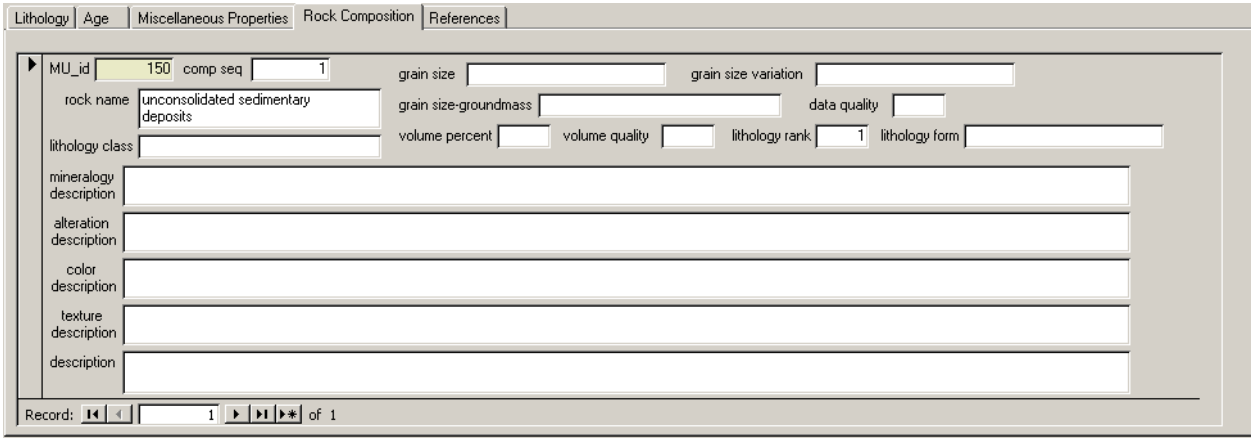

Figure 18*D*. View of layout for the Rock Composition-tabbed page in the **MUO_frm** form.

Lithology page points to the **NR_Lith** table, Age points to the **Stratigraphic_Age** table, Miscellaneous Properties to the **NR_Unit_Characteristic** table, Rock Composition to the **NR_Rock_Comp** table, and References to the **NR_Bib** table.

MUO_Link_subfrm Form

The **MUO_Link_subfrm** form (fig. 20) displays the correlation between the map-unit identifier for the original map unit (*MU_id*) and the map-unit identifier for the compiled geologic-map unit (*CG_MU_id*) from the **MUO_Link** table.

NR_Bib subfrm Form

The **NR_Bib subfrm** form (fig. 21) is displayed on the References-tabbed page of the **MUO_frm** form and contains text boxes for all the fields in the **NR_Bib** table. The data is linked to records in the **MUO** table by the *source_id* field (which should never be edited or revised in this form). Data entered in this form follow standards set by the USGS. If the cited publication is part of another publication, then the larger-work information (author and title) is entered into the text boxes designated LW1 for first larger work and LW2 for second larger work (where LW1 would be nested inside the larger work LW2).

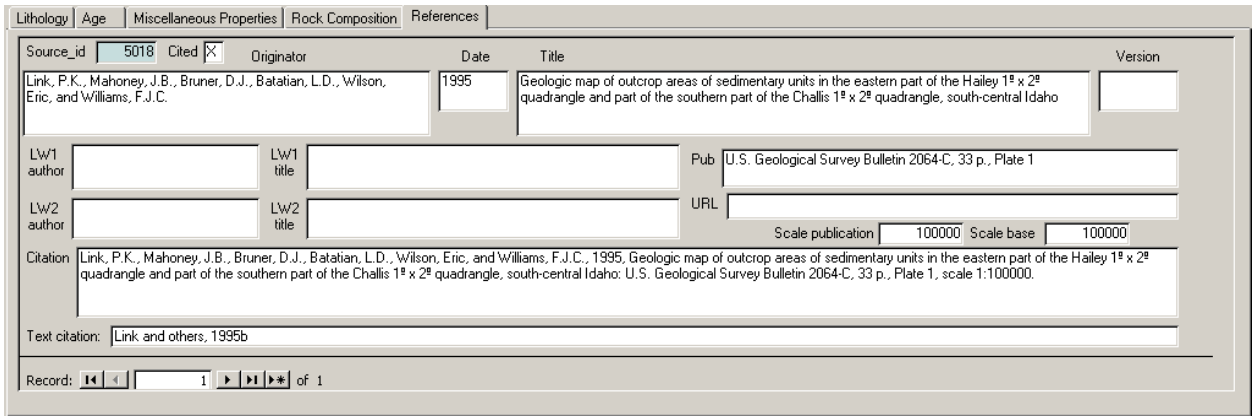

Figure 18*E*. View of layout entries for the References-tabbed page in the **MUO_frm** form.

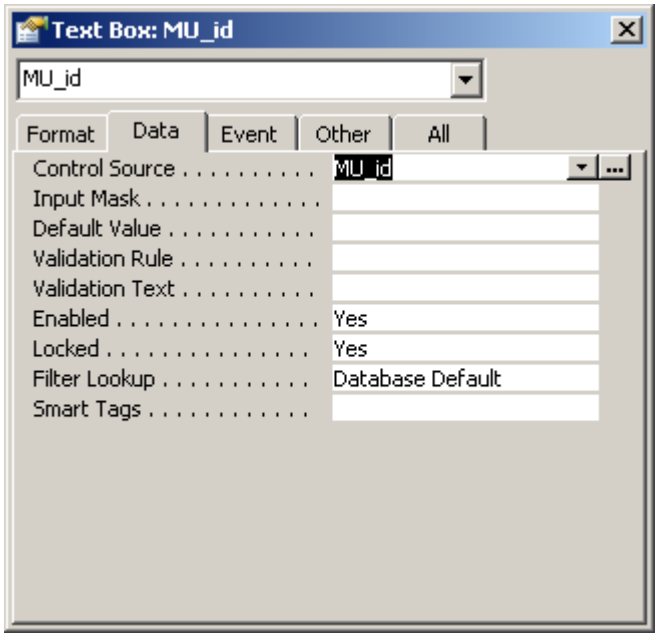

Figure 19. Properties for Text Box MU_id on the Data tab of the Design view of the **MUO_frm** form. (Note "Locked" on the Data tab is set to "Yes" to keep users from modifying the entry for **MU_id**.

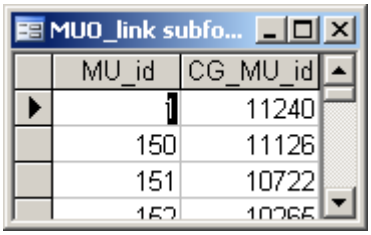

Figure 20. **MUO_Link**_subfrm form. (For example, it shows that the original map unit with **MU_id** = 1 correlates to the compiled geologic-map unit with **CG_MU_id** = 11240, for the selected unit.)

This form can be used by itself to enter new references into the database or view existing records. The database contains many references that were acquired by scanning the references lists from the source-map publications and from other sources related to the geology of the northern Rocky Mountain region.

NR_Lith_subfrm Form

The **NR_Lith_subfrm** form (fig. 22) is embedded in the **MUO_frm** form (on the Lithology tab, fig. 18*A*) for entering or editing lithologic data in the **NR_Lith** table. The **NR_Lith_subfrm** form was not designed for use as a standalone data-entry form; thus, navigation buttons on the form were removed to prevent the user from attempting data entry outside of the **MUO_frm** form environment.

NR_Rock_Comp_subfrm Form

The **NR_Rock_Comp_subfrm** form (fig. 23) comprises the Rock Composition-tabbed page in the **MUO_frm** form;

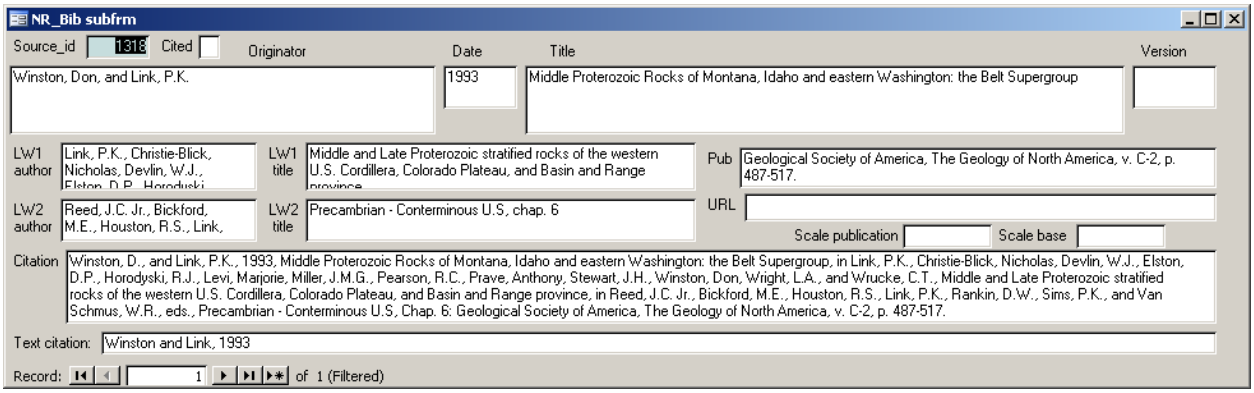

Figure 21. **NR_Bib subfrm** form.

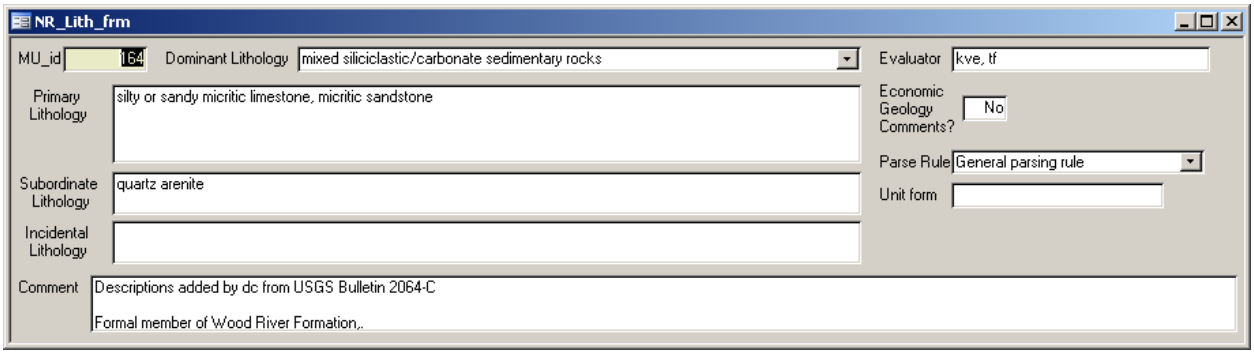

Figure 22. **NR_Lith_subfrm** form.

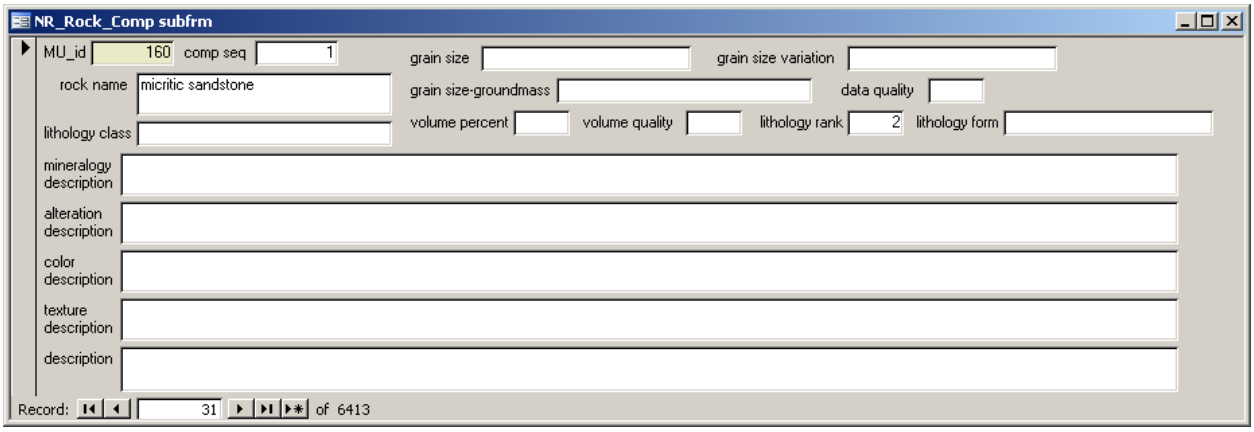

Figure 23. **NR_Rock_Comp_subfrm** form.

the form may be used to enter descriptive information about the mineralogy and alteration of map units in the **NR_Rock_Comp** table. No information other than *MU_id*, composition sequence number, rock name, and lithology ranking was entered into the nrgeo database; the other data fields are empty and available for future attribution.

NR_Unit_Characteristic_subfrm Form

The **NR_Unit_Characteristic_subfrm** form (fig. 24) comprises the Miscellaneous Properties-tabbed page embedded in the **MUO_frm** form Data entered into this tabbed page are stored in the **NR_Unit_Characteristic** table.

Stratigraphic_Age_subfrm Form

The **Stratigraphic_Age_subfrm** form (fig. 25) comprises the Age-tabbed page that is embedded in the **MUO_frm** form. Data entered into this tabbed page are stored in the **Stratigraphic_Age** table. This entry form is used to document the youngest and oldest stratigraphic ages of a map unit. It also contains a term (in the text box for Comprehensive age) that expresses the age range in geologic-period or higher-level age terms. The Comprehensive-age term should reflect geologic period when the age represents a period or a level lower than period, and era when the age term is a level higher than period, but lower or equal to era in rank.

Conclusions

The relational database **nrgeo.mdb** contains detailed information for 3,465 geologic-map units (2,136 units from source maps and 1,329 units from a regional-map compilation) used in creating a GIS for the geology of the northern Rocky Mountains. Data was entered into the relational database in order to structure it in a consistent format, perform quality-control checks, and export selected data for incorporation into the spatial database **nr_geo** of Zientek and others (2005).

A digital geologic database provides a mechanism to produce a consistent description of geology and consolidate diverse descriptions from many authors. Spelling errors can be prevented and quality controls can be used to check for some kinds of errors. A benefit of relational databases is that the geologist is not limited in describing geologic characteristics to one set or view of temporal-physical-chemical parameters. Another advantage of databases over paper maps is the ability to rapidly create generalized products for types of information that are hierarchical, such as stratigraphic time and rock types.

A relational database combined with a spatial database provides a mechanism to create a variety of maps that present differing views of geology. The database provided with this report was used in the production of the spatial database (**nr_geo**) by Zientek and others (2005), and it also contains additional information. Figures 26 through 29 are examples of

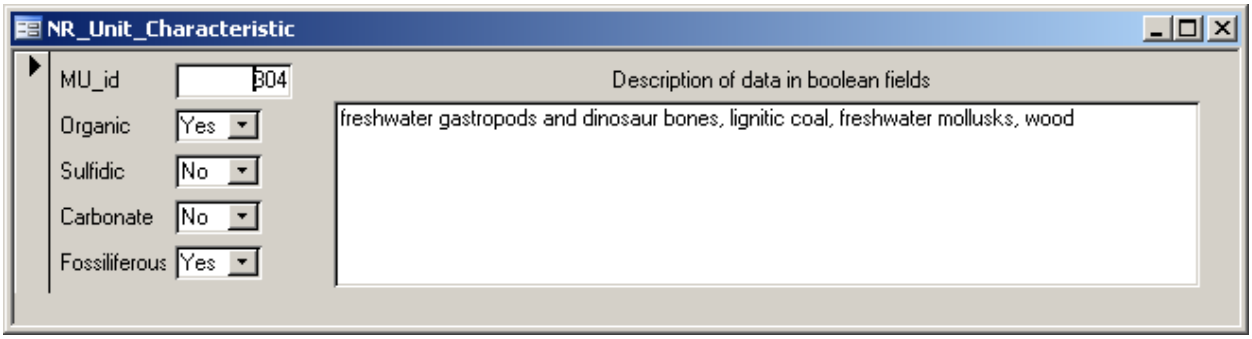

Figure 24. **NR_Unit_Characteristic_subfrm** form.

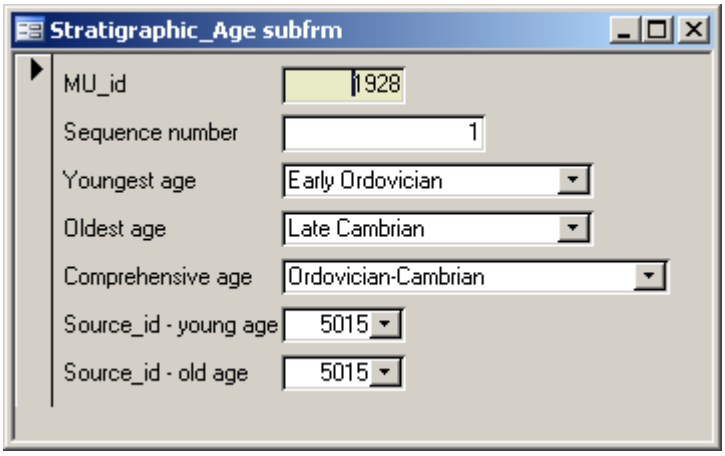

Figure 25. **Stratigraphic_Age_subfrm** form.

some of the types of maps that can be made by combining this database with the associated spatial database.

Geologic maps usually reflect the emphases of their authors, illustrating different goals, purposes, and interests. Paper geologic maps are limited to a two-dimensional product that often tries to provide the user with multidimensional information. These limitations can present difficulties when using nondigital, published geologic maps to produce a database that contains consistent descriptions across several mapped areas. When diverse source map materials are compiled, these difficulties are exacerbated. For example, editors/authors of adjoining maps may combine geologic units in different groupings, emphasize different ages or different rock types, and provide differing styles of rock-unit descriptions. As is shown in figures 27 and 28, these differences create distinct breaks across some map boundaries, which reflects the inconsistency in map-unit descriptions.

In this endeavor it was not always possible to code information for map units so that a user could produce a consistent two-dimensional map product for each of the classes of data stored in the database. For example, on one of the source maps an author may have lumped all Paleozoic sedimentary formations into one map unit with little or no description of the rocks, while on an adjoining map, units in each geologic period of the Paleozoic may have been individually identified and described. By using the data in this database to make a map based on geologic era for example, a consistent product could be created; however, attempting to display the geologic units by geologic period may result in a "fault" at the source-map boundaries (fig. 26). This type of apparent mismatch can occur for almost every type of information included in this database.

Despite the limitations just described, many useful map compilations can be created from the database. Lithology and age have been standardized. Difficulties with the data can be easily seen when this database is attached to the **nr_geo** database of Zientek and others (2005), thereby giving the user a visual display so that the problem areas can be easily identified and fixed.

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Figures 26–29

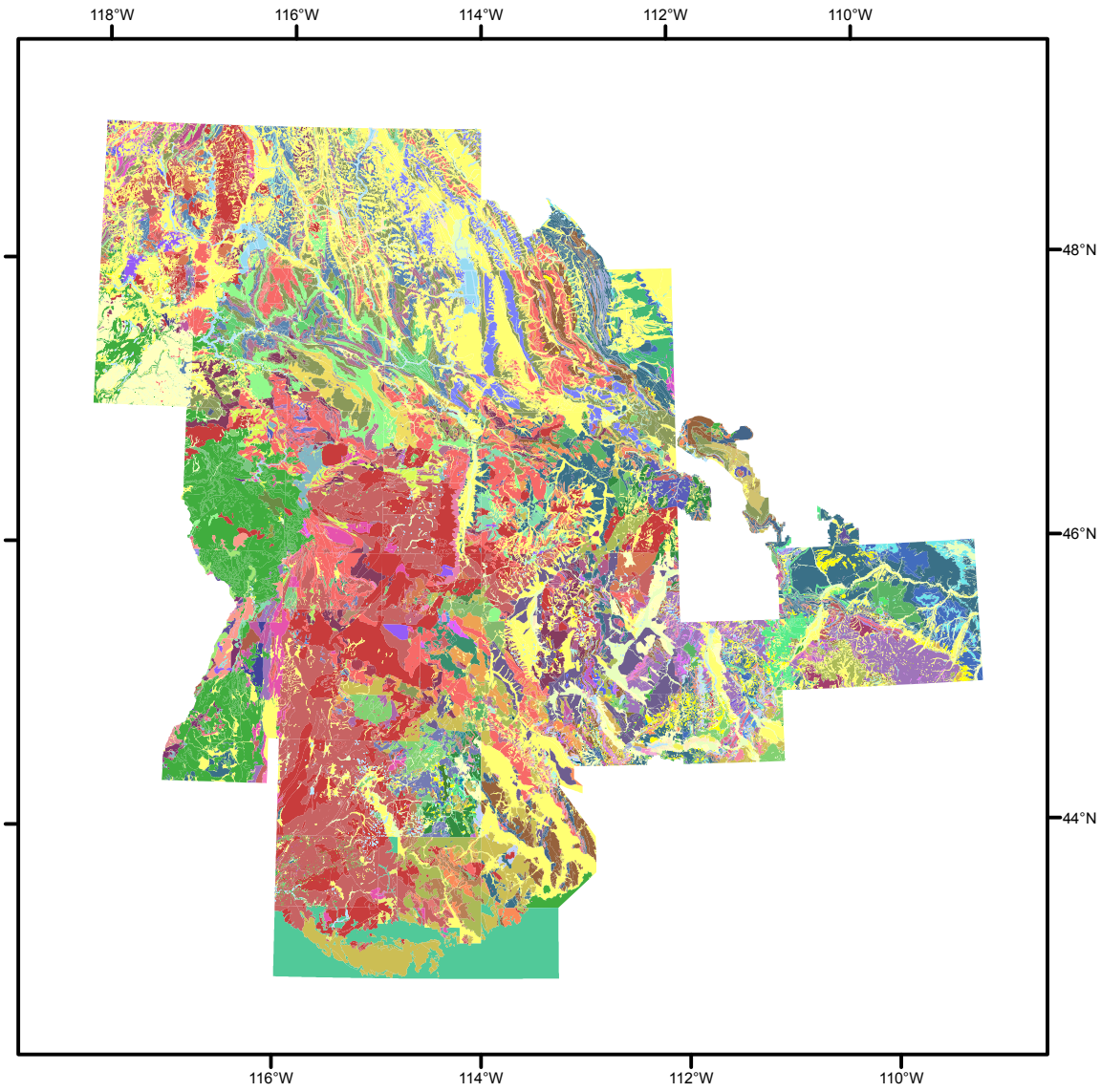

Figure 26. Dominant-lithology map of the northern Rocky Mountains.

Figure 26—Continued.

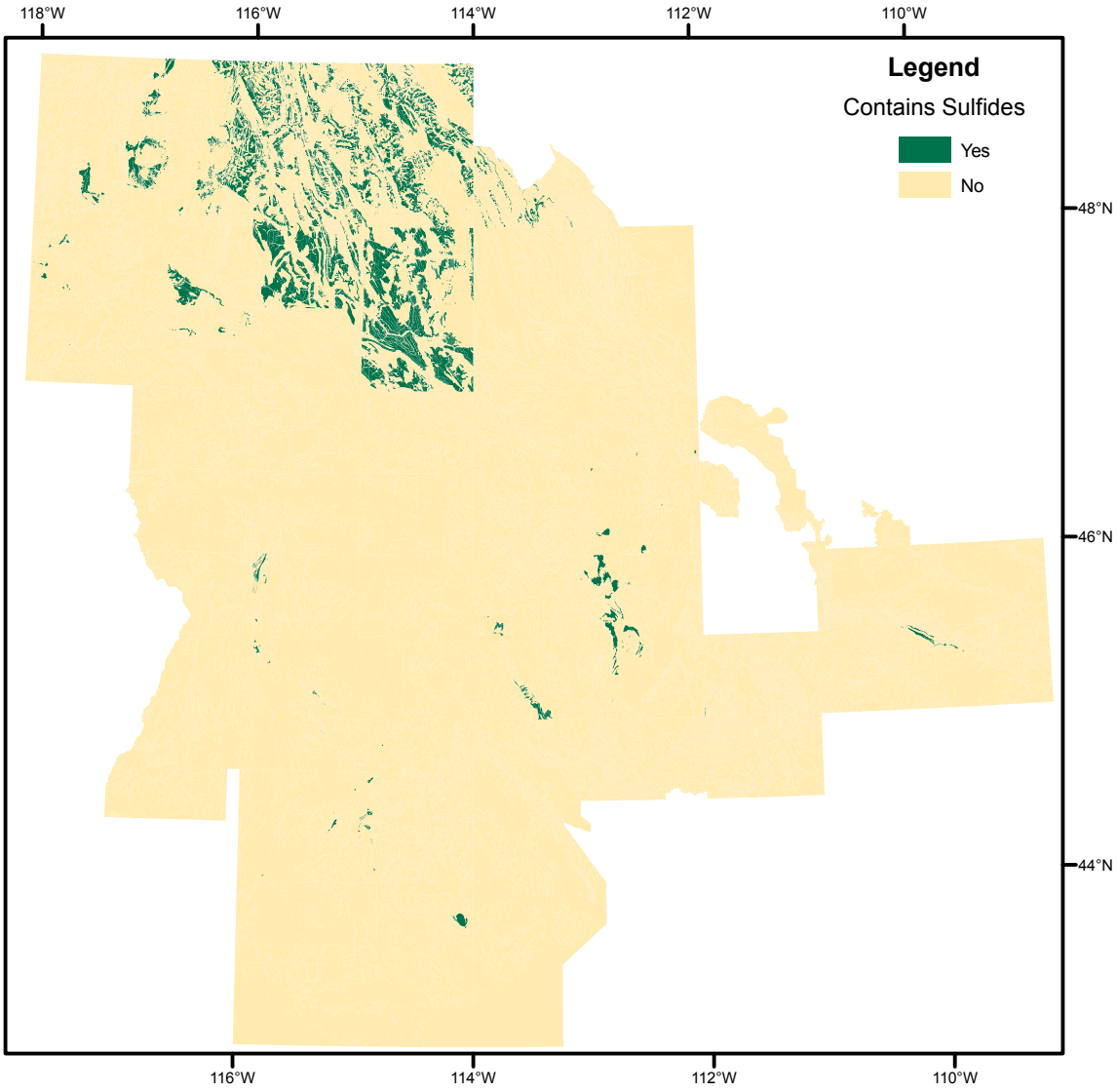

Figure 27. Geologic units in the northern Rocky Mountains described by source authors as containing sulfide minerals.

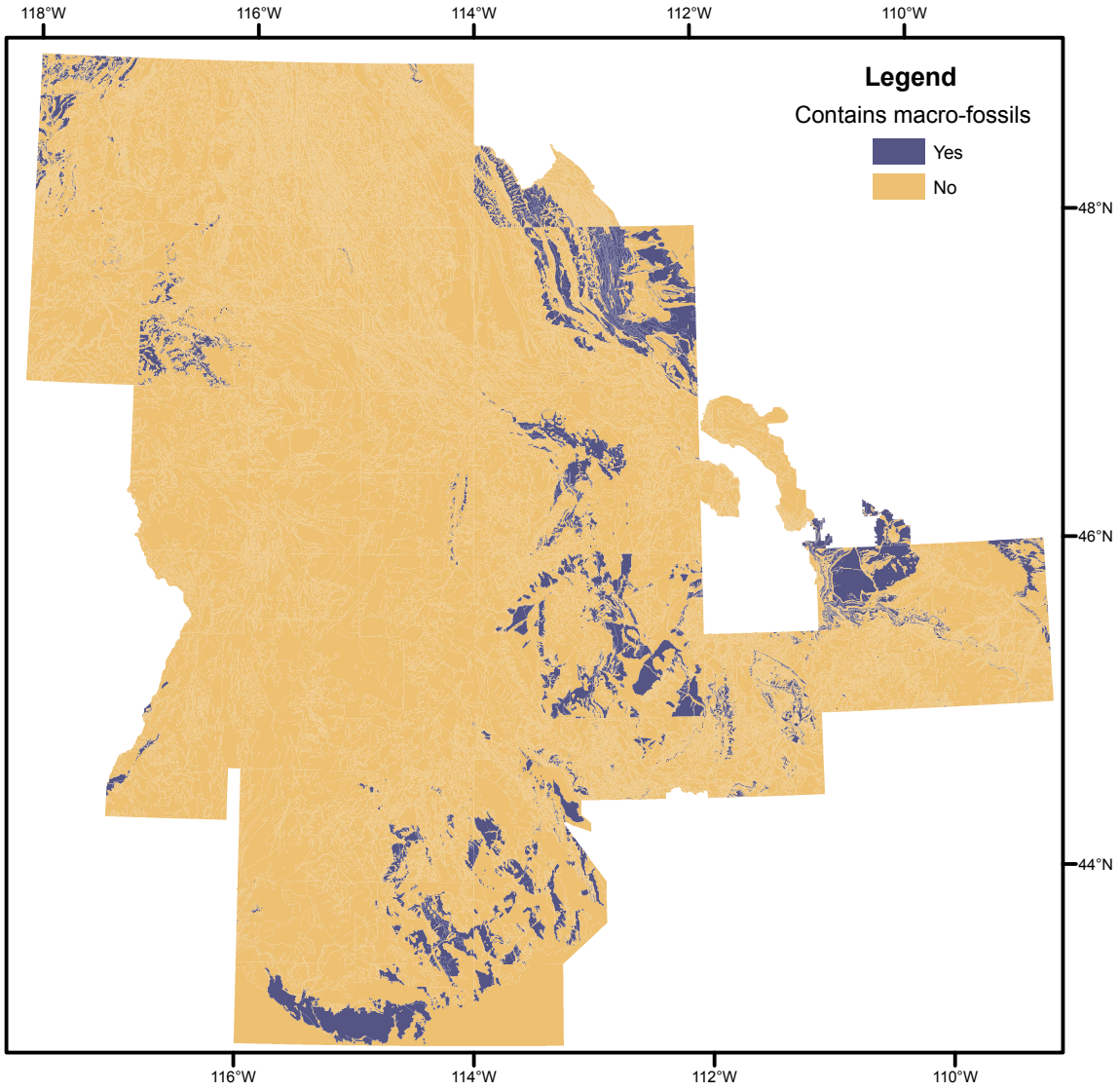

Figure 28. Geologic units in the northern Rocky Mountains described by source or secondary authors as containing fossils.

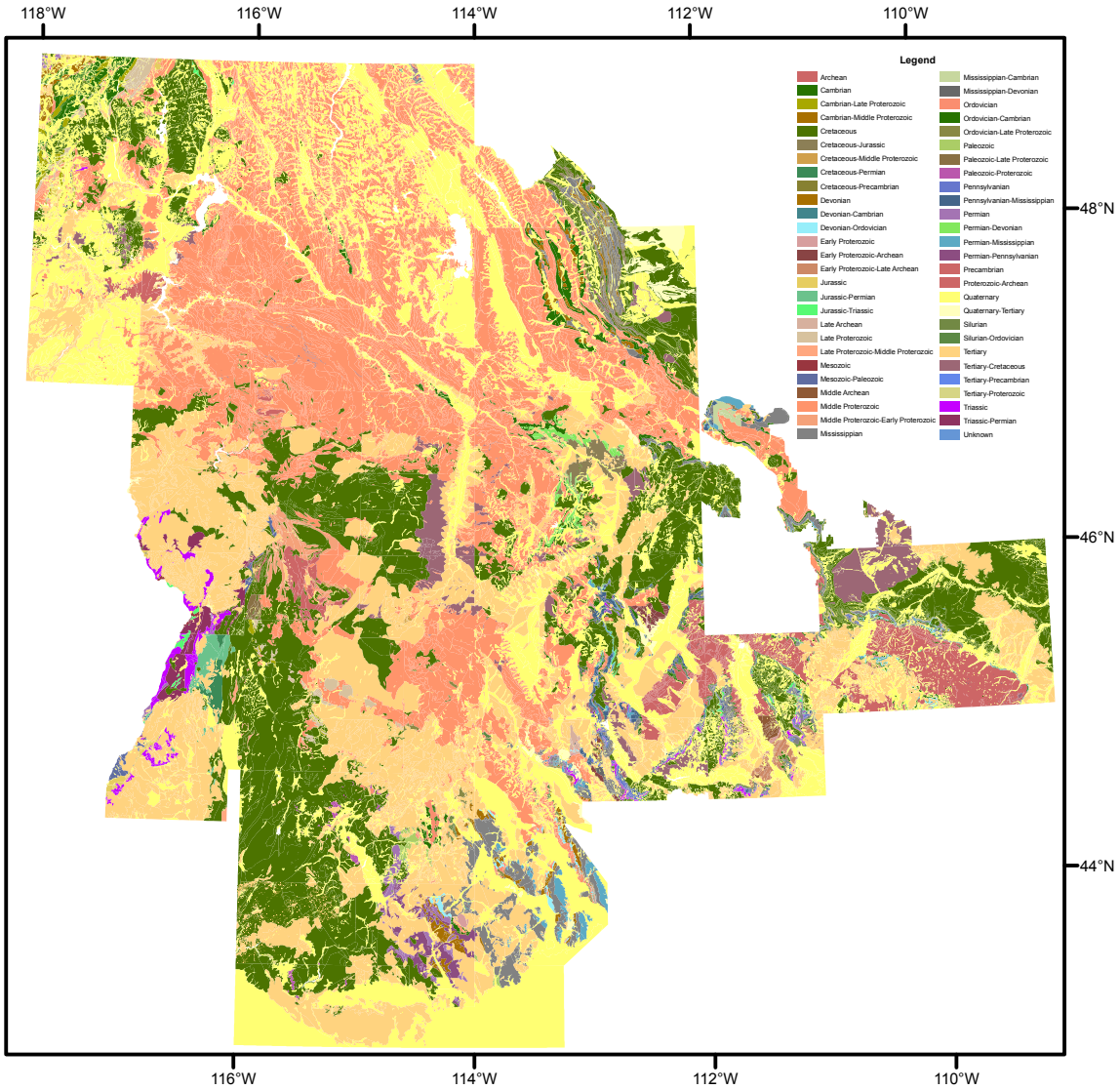

Figure 29. Stratigraphic-age map of the northern Rocky Mountains.

Tables 1–19

Table 1. List of objects (tables, queries, and forms) in the **nrgeo.mdb** database.

Tables	
Data table name	**Description**
MUO	Data table: Description of map units in the geologic map compilation of the northern Rocky Mountains by Zientek and others (2005).
NR_Bib	Data table: Bibliography of geologic literature for the northern Rocky Mountains of Idaho, Montana, and Washington.
NR_Lith	Data table: Lithologic (rock composition) information for geologic map units.
NR_Map_Title	Data table: Titles of source maps.
NR_Rock_Comp	Data table: Design based on Rock_Composition table in North American Digital Geologic Data Model v. 4.3, Johnson and others, 1999 -- data added by parsing the composition data from **NR_Lith** table into the *rock_name* field.
NR_Unit_Characteristic	Data table: Information about rock units based on selected properties.
Stratigraphic_Age	Data table: Stratigraphic ages for rock units in northern Rocky Mountains.
Look-up table name	**Description**
Lith_Process_LU	Look-up table: List of processes used to parse rock terms from source descriptions into primary, secondary, and incidental categories in **NR_Lith** table. [Processes are described by Zientek and others (2005, Appendix E).]
NR_Eval_LU	Look-up table: Definitions (names of coders) of initials used in *Lith_eval* field of the **NR_Lith** table.
NR_Lith_LU	Look-up table: List of valid terms for attributing the *dom_lith* field of the **NR_Lith** table.
Strat_Age_LU	Look-up table: Age terms to use in *Strat_name* field in **Stratigraphic_Age** table.
Strat_Rank_LU	Look-up table: Stratigraphic-rank terms and codes.
Strat_Time_Scale_LU	Look-up table: Master list of stratigraphic ages used in northern Rocky Mountains geologic-map compilation.
Unit_Type_LU	Look-up table: Codes used in *unit_type* field of **MUO** table.
Join table name	**Description**
MUO_Link	Join table: **MUO_Link** table links *MU_id* values assigned to original source map units to unique map units created for the regional map compilation by Zientek and others (2005).
MUO_Source_Link	Join table: **MUO_Source_Link** table joins **MUO** table to **NR_Bib** table by using a one-to-many-to-one relationship.
Tree table name	**Description**
NR_Lith_Tree	Tree table: Hierarchical level within a lithologic classification system for term listed in **NR_Lith _LU** table.
Strat_Tree	Tree table: Stratigraphic Tree table of hierarchical relationship of age terms.
Queries	
Select queries	**Description**
Lith_hierarchy_source_qry	Select Query: Selects specific fields and data from **NR_Lith**, **NR_Lith_LU**, and **NR_Lith_Tree** tables. Its output is used by **Lith_hierarchy_source_crosstab_qry**.
NR_desc_pdf_qry	Select Query: Selects map-unit descriptions (from *MU_desc* field in the **MUO** data table) as specified for use in the form **NR_pdf_qry_frm**.
Strat_age_min_hierarchy_qry	Select Query: Selects specific fields and data from **Stratigraphic_Age**, **Strat_Time_Scale_LU**, and **Strat_Tree** tables. Its output is used by **Strat_age_min_hierarchy_crosstab_qry**.
Crosstab queries	**Description**
Lith_hierarchy_source_crosstab_qry	Crosstab Query: Provides hierarchical list of dominant lithologies for map units; uses **Lith_hierarchy_source_qry**.
Strat_age_min_hierarchy_crosstab_qry	Crosstab Query: Provides hierarchical list of stratigraphic-age terms according to the youngest age of the map units; uses **Strat_age_min_hierarchy_qry**.

Table 1. List of objects (tables, queries, and forms) in the **nrgeo.mdb** database.—Continued

Tables	
Data table name	**Description**

Parameter queries	**Description**
Age_hierarchy_parameter_qry	Parameter Query (Interactive Select Query): Generalizes geologic age of map unit to hierarchical rank specified by user when query is run.
Forms	
Startup, introductory, and main forms	**Description**
1-Startup_frm	Startup form: Provides user with preset choices of database operations.
SplashScreen	Form displays for 5 seconds when database opens, showing publication credits.
MUO_frm	Master data-entry form for **MUO** table (geologic map-unit objects).
NR_pdf_qry_frm	Form used to output description of map units and related information to an Adobe PDF file published by Zientek and others (2005).
Subforms	**Description**
MUO_Link_subfrm	Subform used on **MUO_frm** showing link between original map units and new units created for northern Rocky Mountains geologic-map compilation.
NR_Bib_subfrm	Subform used on **MUO_frm** for data input into **NR_Bib** table through the *source_id* code
NR_Lith_subfrm	Subform used on **MUO_frm** for data input into **NR_Lith** table.
NR_pdf_Bib_subfrm	Subform used on **NR_pdf_qry_frm** to show references for each record.
NR_Rock_Comp_subfrm	Subform used on **MUO_frm** for data input into **NR_Rock_Composition** table.
NR_Unit_Characteristic_subfrm	Subform used on MUO_frm for data input into **NR_Unit_Characteristics** table.
Stratigraphic_Age_subfrm	Subform used on **MUO_frm** for data input into **Stratigraphic_Age** table.

Table 2. **MUO** table design and summary.

Table name	MUO		
Format	Microsoft Access 2000 data table		
Description	The table provides original geologic map- unit names and labels, new map-unit names and labels, links to references and other data tables		
Keyfield	*MU_id*		
Relations	*MU_id* - 1-to-many relation to *MU_id* field in the **Stratigraphic_Age**, **MUO_Link**, **MUO_Source_Link**, and **NR_Rock_Comp** tables, and 1-to-1 relation to *MU_id* field in **NR_Lith** and **NR_Unit_Characteristics** tables; *map_tile* – many-to-1 to *map_tile* field in **NR_Map_Tiles_LU**; *unit_type* – many-to-1 to *unit_type* field in **Unit_Type_LU**.		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Unique integer for each map unit. Records with *MU_id* > 0 and *MU_id* < 4977 represent original source-map (input) units; records with *MU_id* > or = 10000 represent regional geologic-map (output) units in the map compiled by Zientek and others (2005).
MU_lab_or	Text	20	Map symbol, represented with ASCII characters, used to label original or regional geologic-map units.
MU_lab_gaf_or	Text	20	Map symbol, represented with GeoAgeFullAlpha font-set characters, used to label original or regional geologic-map units.
MU_name_or	Text	255	Name of original or regional geologic- map unit.
MU_type	Text	50	Type of map-unit object (for example, rock unit, structure, metamorphic facies).
MU_desc	Memo	NA	Description of geologic-map unit.
source_id	Number	Long integer	Integer used to identify source of original map-unit description. See the table **NR_Bib** for complete references for the sources.
map_tile	Text	100	Name assigned to geologic map that was the principal source of information used in preparing the regional geologic-map compilation (*for MU_id* > 0 and *MU_id* < 4978) OR Name of the geologic- map compilation (for *MU_id* = 10000 or *MU_id* > 10000).
MU_name	Text	255	Name assigned to regional geologic-map unit in the northern Rocky Mountains geologic-map compilation by Zientek and others (2005).
MU_lab	Text	20	Map symbol, represented with ASCII characters, used to label regional geologic-map units in the northern Rocky Mountains geologic-map compilation by Zientek and others (2005).
MU_lab_gaf	Text	20	Map symbol, represented with GeoAgeFullAlpha font-set characters, used to label regional geologic-map units in the northern Rocky Mountains geologic map compilation by Zientek and others (2005).
unit_type	Text	2	Designator indicating type of stratigraphic unit: F = formal stratigraphic unit, IF = informal member of formal stratigraphic unit, I = informal unit, U = unconsolidated material.

Table 3. **NR**_Bib table design and summary.

Table name	**NR_Bib**		
Format	Microsoft Access 2000 data table		
Description	The table provides reference information for the units.		
Keyfield	*source_id*		
Relations	1-to-many relation to *source_id* field in **MUO_Source_Link** table		
Field name	**Data type**	**Field size**	**Description**
source_id	Number	Long integer	Unique source identification number.
cited	Text	1	X – Indicates that data source was cited by Zientek and others (2005); no entry indicates that source was not cited by Zientek and others (2005).
originator	Text	255	Name(s) of author(s) or compiler(s) of data source.
date	Text	255	Date of data-source publication, OR date that data were made available for our use, OR comments regarding publication status or how data was acquired. Year in brackets indicates publication-release date if different from publication date.
version	Text	255	Version of the publication.
title	Memo		Complete title of the data source.
lw1_author	Text	255	Name of author(s) or compiler(s) of the first larger work when cited publication is within a larger publication.
lw1_title	Text	255	Title of the first larger work.
lw2_author	Text	255	Name of the author(s) or compiler(s) of the second larger work when larger work is within another publication.
lw2_title	Text	255	Title of the second larger work.
pub	Text	255	Publisher, publication series and number (or other designation), and remainder of reference in U.S. Geological Survey reference style for published data.
scale_pub	Number	Long integer	Source scale (given as the denominator of the proportional fraction) of the published geologic map.
scale_base	Number	Long integer	Source scale (given as the denominator of the proportional fraction) of the original base map on which the geology was mapped or compiled.
URL	Text	255	Uniform Resource Locator; an address that specifies the location of a file on the Internet.
citation	Memo		Full citation for data source in U.S. Geological Survey reference style.
text_citation	Text	100	Abbreviation of citation for use when data source is cited within the body of a report.

Table 4. **NR**_Lith table design and summary.

Table name	**NR_Lith**		
Format	Microsoft Access 2000 data table		
Description	The table provides description of the lithology of the unit.		
Keyfield	*MU_id*		
Relations	*MU_id* - 1-1 relation to *MU_id* field of **MUO** table; *dom_lith* – many-to-1 relation to *lith_name* in **NR_Lith_LU**; *lith_process* – many-to-1 relation to *lith_process* in **Lith_Process_LU**.		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Unique identifier for map unit.
dom_lith	Text	100	Dominant rock or rock material present in the geologic entity that is represented by a map unit. Attributes were selected from the *Lith_name* field of the **NR_Lith_LU** table. No data means that the evaluator was unable to determine a rock type from the source material descriptions. [The *dom_lith* field corresponds to the *lname_dom* and *uname_dom* fields in **NR_GEO.LITH** and **NR_GEOL.UN** tables, respectively, of Zientek and others (2005).]
primary_lith	Memo		Primary rock or rock-material terms describing map units, as reported in source publications. Sometimes modified by secondary sources if primary-source description was deficient. (The field corresponds to *name_majr1* and *name_majr2* fields in **NR_GEO.LITH** table and *name_major* field in **NR_GEOLUN** table of Zientek and others (2005).)
subordinate_lith	Text	255	Minor rock or rock-material terms describing map units, as reported in source publications. [The field corresponds to *name_minor* field in **NR_GEO.LITH** and **NR_GEOL.UN** tables of Zientek and others (2005).]
incidental_lith	Text	255	Incidental rock or rock-material terms describing map units, as reported in source publications. [The field corresponds to *name_other* field in **NR_GEO.LITH** and **NR_GEOL.UN** tables of Zientek and others (2005).]
lith_eval	Text	100	Initials of person(s) responsible for interpreting and entering lithologic data into the table or proofing the table. (Evaluators' names are listed in the **NR_Eval_LU** look-up table.)
unit_form	Text	50	Geologic or geomorphic form of the mapped geologic unit.
lith_comment	Memo		Comments from evaluator(s).
econ_geol	Yes/No		Notation indicating an economic geology component in the map-unit description: Yes = economic component present, No = economic component is not present.
lith_process	Text	50	Parsing rule used to extract data to the *primary_lith*, *subordinate_lith*, and *incidental_lith* fields.

Table 5. **NR_Map**_Title table design and summary.

Table name	**NR_Map_Title**		
Format	Microsoft Access 2000 data table		
Description	The table provides a full and abbreviated name for maps that were the source of data.		
Keyfield	*map_tile*		
Relations	1-to-many relation to *map_tile* field in **MUO** table		
Field name	**Data type**	**Field size**	**Description**
map_tile	Text	100	Name for the map that is the principal source of information. The name is coined by combining an abbreviation of a topographic map or National Forest name and the published map scale.
title	Text	255	Title on geologic map that was source of the geologic mapping.
spatial_DB_name	Text	100	Name of geology spatial database used to make northern Rocky Mountain GIS (nrgeo) in Zientek and others (2005).

Table 6. **NR_Rock**_Comp table design and summary.

Table name	**NR_Rock_Comp**		
Format	Microsoft Access 2000 data table		
Description	The table provides information on characteristics of rocks within the unit.		
Keyfield	*MU_id*, *comp_seq*, *lith_rank*		
Relations	Many-to-1 relation of *MU_id* field to *MU_id* field in **MUO** table		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Map- unit identification number for map unit-linking field to **MUO** table.
comp_seq	Number	Long integer	Unique identification number of a composition within a rock unit. Also indicates sequence number for displaying descriptive information about this composition within a rock-unit description. This order is based on an assumption that the authors of the source publications sequenced from most to least abundant lithology in their descriptions.
rock_name	Text	255	A free-text attribute for storing the map author's preferred complete name for the rock composition.
lith_class	Text	255	A lithologic classification term.
lith_rank		Integer	Rank is a numeric value indicating importance, with 1 meaning most important rock type to 3 meaning rarely present rock type. Coding based on presence in *primary_lith* (1), *subordinate_lith* (2), or *incidental_lith* (3) fields of **NR_Lith** table. There may be more than one rock type with the same *lith_rank* number.
lith_form	Text	50	A form or morphology-classification term.
vol_percent	Number	Integer	An estimate of the volume-percent of the composition within the rock unit.
vol_quality	Number	Integer	Quality of the volume percent estimate (entered as a percent number between 0 and 100).
mineralogy_desc	Text	255	A mineral modifier associated with the rock name, or description of the mineralogy of the composition.
color_desc	Text	255	A description of the color or colors of the composition.
texture_desc	Text	255	A description of the texture of the composition.
grain_size	Text	50	A description of grain size.
grain_size_variation	Text	50	A description of the variation in grain size.
grain_size_grdmass	Text	50	Grain size of the groundmass.
alteration_desc	Text	255	A description of any alteration associated with the composition.
data_quality	Number	Integer	Quality of the description of the rock. Value from 1 to 10, where 10 is best.
description	Memo		A text description of this composition.

Table 7. **NR_Unit**_Characteristic table design and summary.

Table name	**NR_Unit_Characteristics**		
Format	Microsoft Access 2000 data table		
Description	The table provides information on chemical characteristics, fossils, and organic matter of the unit.		
Keyfield	*MU_id*		
Relations	1-to-1 relation to ***MU_id*** field in **MUO** table		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Map unit identification number for map unit-linking field to MUO table.
organic	Text	3	Yes indicates organic material present in map unit. No means no description of organic material is provided in source description.
sufidic	Text	3	Yes indicates sulfur present in map unit. No means no description of sulfur-bearing material is provided in source description.
carbonate	Text	3	Yes indicates carbonate minerals present in map unit. No means no description of carbonate material is provided in source description.
fossiliferous	Text	3	Yes indicates macro-fossils present in map unit (Stromatolites not included). No means no macro-fossils are described in source publication.
oscf_desc	Memo		Explanation for the "Yes" selection for *organic*, *sulfidic*, *carbonate*, or *fossiliferous* fields.

Table 8. **Stratigraphic_Age** table design and summary.

Table name	**Stratigraphic_Age**		
Format	Microsoft Access 2000 data table		
Description	The table provides information on the stratigraphic age of each unit.		
Keyfields	*MU_id*, *strat_seq*		
Relations	*MU_id* - many-to-1 relation to *MU_id* field in **MUO** table, s*trat_name* relates to *strat_name* in **Strat_Age_LU** table, *min_strat_name* and *max_strat_name* relate to *min_max_strat_name* in **Strat_Age_LU** table		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Map unit identification number for map unit-linking field to **MUO** table.
strat_seq	Double		Record identifier for a specific time interval for the unit identified by the *MU_id*. For maps from Idaho Geological Survey, IGS numbers are used.
min_strat_name	Text	50	The minimum time-stratigraphic age selected from the Stratigraphic Time Scale table.
max_strat_name	Text	50	The maximum time-stratigraphic age selected from the Stratigraphic Time Scale table.
strat_name	Text	50	Stratigraphic-age term for geologic-period level (or hierarchically above period if necessary). Contains combined-age terms when minimum and maximum ages differ.
min_source_id	Number	Long integer	Unique identification number of an information source for the minimum-age reference from the source table.
max_source_id	Number	Long integer	Unique identification number of an information source for the maximum-age reference from the source table

Table 9. **NR_Eval_LU** table design and summary.

Table name	**NR_Eval_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides the full name of the evaluators in the *lith_eval* field in the NR_Lith table.		
Keyfield	*lith_eva***l**		
Relations	None, used to check correct use of initials in *lith_eva***l** field of **NR_Lith** table		
Field name	**Data type**	**Field size**	**Description**
lith_eval	Text	5	Initials of the person who evaluated and coded lithologic data.
lith_eval_name	Text	50	Name of the person who evaluated and coded lithologic data.

Table 10. **NR_Lith_LU** table design and summary.

Table name	**NR_Lith_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides a valid list of terms for the *dom_lith* field in the **NR_Lith** table and a hierarchy for those terms.		
Keyfield	*lith_name*		
Relations	1-to-many relation to *dom_lith* field in **NR_Lith** table		
Field name	**Data type**	**Field size**	**Description**
lith_name	Text	100	Name describing lithologic character of rock unit (from a hierarchical classification of lithology terms compiled for the **nrgeo.mdb** database).
lith_id	Number	Long integer	Unique identification number for lithologic term. Links to the **NR_Lith_Tree** table to identify parent-child relations in a hierarchical classification system.
lith_level	Number	Integer	A numeric value for the level in a hierarchical classification of lithologic terms.
lith_defn	Memo		Geologic definition of the lithologic term.
defn_type	Text	10	Type of material being defined: rock, water, or unit (where type of material is either unconsolidated material or a group/mixture/suite of rock types).
lith_ref	Text	255	Abbreviated citation for source of term used in *Lith_name* field.
source_id	Number	Long integer	Unique identification number for publication cited in *lith_ref* field. Links to *source_id* field in **NR_Bib** table.

Table 11. **Strat_Age_LU** table design and summary.

Table name	**Strat_Age_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides a list of valid terms for the *strat_name* field in the **Stratigraphic_Age** table.		
Keyfield	*strat_age_id*		
Relations	1-to-many relation *min_max_strat_name* to *min_strat_name* and *max_strat_name* field and *strat_name* to *strat name* in **Stratigraphic_Age** table		
Field name	**Data type**	**Field size**	**Description**
strat_age_id	Number	Long integer	Unique identification number for a stratigraphic-age term.
min_max_strat_name	Text	50	Unique list of combined minimum-maximum-age terms.
strat_name	Text	50	List of combined minimum-maximum-age terms at geologic-period level for Phanerozoic and era level for Precambrian when possible.
min_strat_age	Number	Double	Minimum numerical age, in millions of years.
max_strat_age	Number	Double	Maximum numerical age, in millions of years.

Table 12. **Strat_Rank_LU** table design and summary.

Table name	**Strat_Rank_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides a way to order stratigraphic age terms according to hierarchical ranking.		
Keyfield	*strat_rank*		
Relations	1-to-many relation to *strat_rank* field of **Strat_Time_Scale_LU** table		
Field name	**Data type**	**Field size**	**Description**
strat_rank	Text	50	A keyword representing the rank of the time-stratigraphic term.
strat_level	Number	Long integer	A numeric value for the level in the hierarchy of time-stratigraphic terms.

Table 13. **Strat_Time_Scale LU** table design and summary.

Table name	**Strat_Time_Scale_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides a list of valid terms for the *min_strat_age* and *max_strat_age* fields in the **Stratigraphic_Age** table.		
Keyfield	*strat_id*		
Relations	1-to-many relation to *strat_id* field in **Strat_Tree table**		
Field name	**Data type**	**Field size**	**Description**
strat_id	Number	Long integer	A unique identifier for the strat_name.
strat_name	Text	255	The time-stratigraphic name for the time interval.
strat_rank	Text	10	A keyword representing the rank of the time-stratigraphic term. Must be included in the **Strat_Rank_LU** table.
min_strat_age	Number	Double	Minimum numerical age, in millions of years.
max_strat_age	Number	Double	Maximum numerical age, in millions of years.
min_source_id	Number	Long integer	Unique identification number of an information source for the minimum-age reference.
max_source_id	Number	Long integer	Unique identification number of an information source for the maximum-age reference.

Table 14. **Lith_Process_LU** table design and summary.

Table name	**Lith_Process_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides a list of valid terms for the *lith_process* field in the **NR_Lith** table.		
Keyfield	*lith_process*		
Relations	1-to- many relation to *lith_process* field of **NR_Lith** table		
Field name	**Data type**	**Field size**	**Description**
lith_process	Text	50	Term describing the process used to parse rock terms into categories that infer the importance of those rocks within a map unit.
lith_process_desc	Memo		Description of the process to interpret and convert an author's map-unit description into a three-level ranking system of importance of a rock type within a map unit. Description taken from Zientek and others (2005).

Table 15. **Unit_Type_LU** table design and summary.

Table name	**Unit_Type_LU**		
Format	Microsoft Access 2000 look-up table		
Description	The table provides a list of valid terms for the *unit_type* field in the **MUO** table.		
Keyfield	*unit_type*		
Relations	1-to-many relation to *Unit_type* field in **MUO** table		
Field name	**Data type**	**Field size**	**Description**
unit_type	Text	2	Abbreviation for categorization of geologic-unit name.
unit_type_desc	Text	50	Descriptive name for *unit_type* field: Formal unit, informal part of formal unit, informal unit, unconsolidated unit.
definition	Text	255	Definition of *unit_type_desc* term.

Table 16. **MUO_link** table design and summary.

Table name	**MUO_link**		
Format	Microsoft Access 2000 join table		
Description	The table provides a link between map units used in different publications.		
Keyfield	*MU_id, CG_MU_id*		
Relations	*MU_id* and *CG_MU_id* many-to-1 relation to *MU_id* field in **MUO** table		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Unique integer for map unit. Records with *MU_id* > 0 and < 4,977 represent original source-map (input) units; records with *MU_id* > = 10,000 represent regional geologic-map (output) units in the map compilation by Zientek and others (2005).
CG_MU_id	Number	Long integer	Unique intermediate identifier for regional geologic-map (output) unit.

Table 17. **MUO_Source_Link** table design and summary.

Table name	**MUO_Source_Link**		
Format	Microsoft Access 2000 join table		
Description	The table provides link between map units and bibliographic references		
Keyfield	*MU_id, source_id*		
Relations	*MU_id* many-to-1 relation to *MU_id* in **MUO** table, *source_id* many-to-1 relation to *source_id* in **NR_Bib** table		
Field name	**Data type**	**Field size**	**Description**
MU_id	Number	Long integer	Unique integer for map unit.
source_id	Number	Long integer	Integer used to identify source of original map-unit description. See the **NR_Bib** table for complete references for the sources.

Table 18. **NR_Lith_Tree** table design and summary.

Table name	**NR_Lith_Tree**		
Format	Microsoft Access 2000 tree table		
Description	The table provides links to between hierarchically related lithologic terms for each map unit.		
Keyfield	*parent_lith_id*, *lith_id*		
Relations	*parent_lith_id* and *lith_id* many-to-1 relation to *lith_id* in **NR_Lith_LU** table		
Field name	**Data type**	**Field size**	**Description**
parent_lith_id	Number	Long integer	Lithology identification number of the parent lithology term to *lith_id*.
lith_id	Number	Long integer	Identification number for a lithology term in the **NR_Lith_LU** table.

Table 19. **Strat_Tree** table design and summary.

Table name	**Strat_Tree**		
Format	Microsoft Access 2000 tree table		
Description	The table provides links to hierarchically related terms for stratigraphic ages for each map unit.		
Keyfield	*strat_id*, *parent_strat_id*		
Relations	Many-to-1 relation between *strat_id* and *strat_id* field of **Strat_Time_Scale_LU** table.		
Field name	**Data type**	**Field size**	**Description**
strat_id	Number	Long integer	An identification number for a time-stratigraphic interval from the **Stratigraphic_Time_Scale_LU** table.
parent_strat_id	Number	Long integer	An identification number for a second time-stratigraphic interval from the **Stratigraphic_Time_Scale_LU** table, which is a parent of the first interval.

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